Waste management
in General and Healthcare Waste

care-waste project

A guide to the management of general and healthcare waste

Education and Culture

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General-Healthcare Waste
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General-Healthcare Waste

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Index of abbreviations

"3 R's"	Reduce - Reuse – Recycle
AVV	Abfallverzeichnisverordnung
BMW	Biodegradable municipal waste
C&D	Construction and demolition waste
CEE	Central and Eastern European countries
EC	European Commission
EEA	European Environment Agency
EP	European Parliament
EU	European Union
EUROSTAT	Statistical Office of the European Communities
GDP	Gross domestic product
ICI	Industrial, commercial and institutional waste
IPPC	Integrated pollution prevention and control
kWh	kilowatt hours
MBT	Mechanical biological treatment
MSW	Municipal solid waste
MW	Municipal waste
PCB	Polychlorinated biphenyles
RDF	Refuse derived fuel
t	Tones
TOC	Total organic carbon
UN	United Nations
UNSTAT	United Nations Statistics Division
WE	Western European countries

Chapter 1. SOME WORDS

The creation of waste is as old as mankind. For a very long time it has not been a problem, since all residues produced by men returned to the cycles of nature. As the centuries have passed, waste has become a problem due to population growth and the increasing consumption of natural resources.

Everything we consume eventually becomes waste, maybe the same day it is consumed, maybe twenty years later. While our ancestors used only natural materials, nowadays, technical progress provides some thousands of non-natural chemical substances, forming either part of the products we use, or being used in production processes. If we look at almost any product we consume, maybe a pencil, a plastic bag, a car or even a computer, it is clear that these products cannot find their way back into Mother Earth's cycle of life when thrown away.

Besides household waste there are lots of other industrial wastes, like e.g. *ash* from electric power plants, *manure* from animals, *street sweepings,* and *demolition waste,* having once been the old house across the street. If we sum up all these wastes, we discover that every one of us produces more than about 3 tonnes per person each year. Since these are not currently being recycled completely, we create problems with these wastes, which take the form of litter on the landscape, or as a contamination of air, water and soil.

Everybody can contribute to reduce the problems we have with waste. This training material tries to provide *basic* knowledge about waste and its characteristics, including its *origin, collection, treatment, environmental impact* etc. There is a large amount of background information available in terms of scientific knowledge, technical experience, legal regulations and national situations in European countries.

To ease understanding, the reader of this material is asked to accept some shortfalls in accuracy, and experts might note the lack of detail in some areas.

1.1. Waste – Definition and classification

Within the different regulations and concepts of waste management, there are a range of different terminologies used. The terminology differs especially in statistics interpreted and collected by each governing body. As will be shown in the subsequent chapters, there might occur very differing figures in the production of waste for one and the same country or countries where the actual waste production is almost the same. For two countries A and B with the same "waste production standard" it is possible that country A shows 2.5 tonnes per capita and year, while country B is just producing half a ton. The reason for this in most cases is the (unexplained) inclusion or exclusion of different kinds of waste in the statistics, due to different interpretations from one region to another of what is meant by "waste"; for example:

- "Are recycled materials waste or not?"
- "Is excavated soil from construction work waste or not?"
- "In a figure of "household" waste, is the waste of shops included or not?"

It is obvious that a clear definition is necessary, which kind of waste is meant or included in a certain term or figure. In this training material, we use the most common definitions to understand the meaning of waste. The definitions used here are simplified explanations from different (EU) sources.

We do not pretend to have discovered a final truth but to give the reader an idea of which kinds of waste exist and to provide *categories* that are relevant to its management.

Fig. 1 shows the different types of wastes and their aggregation in generic terms. They are characterized in the following sections.

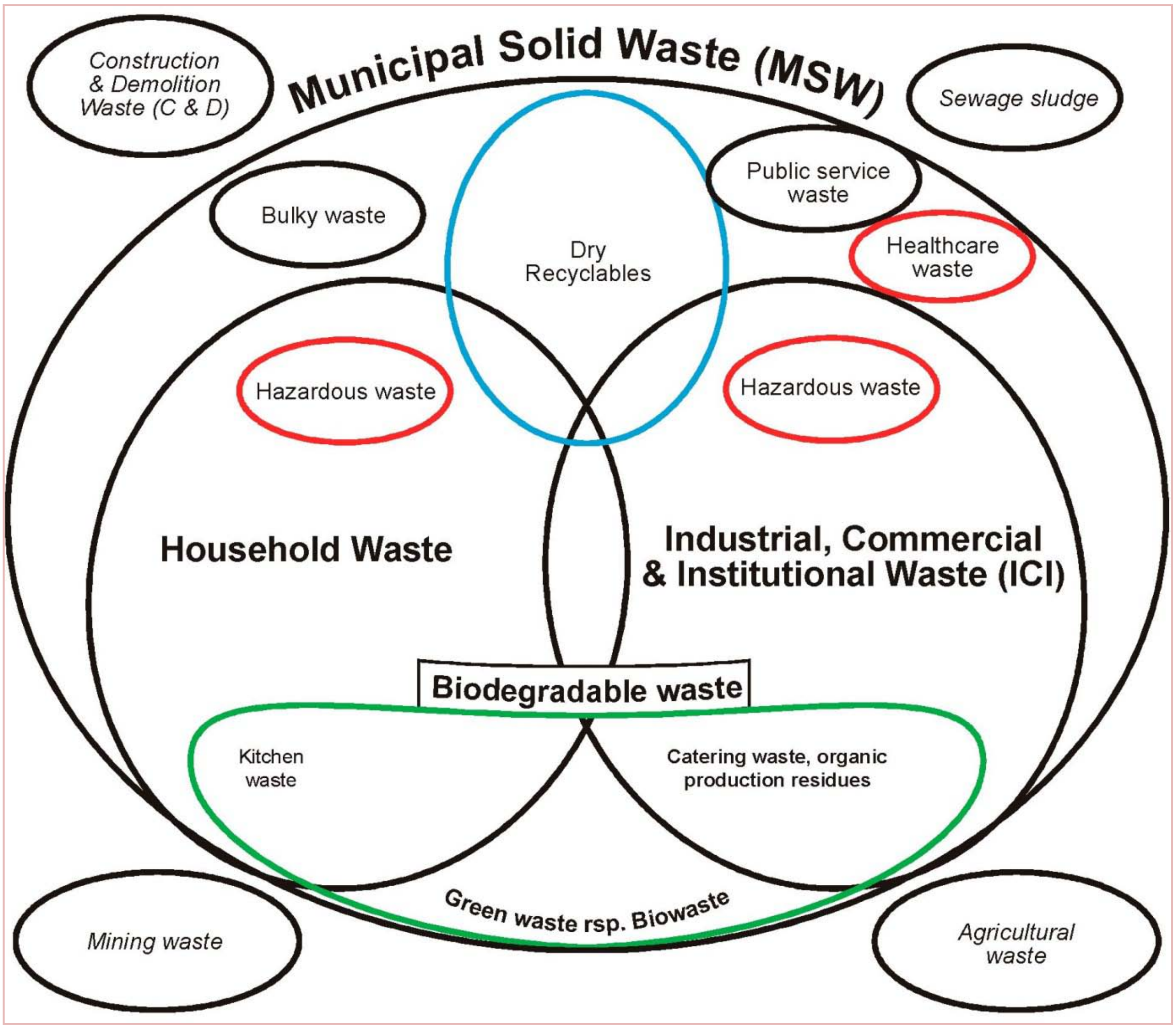


Fig. 1: Classification of waste

Agricultural waste: All residues from crop and animal production, especially harvesting residues and (liquid) manure. Agricultural waste is generated in very high amounts, but is usually almost completely recycled "on site".

Biodegradable waste: Any waste that is capable of undergoing aerobic or anaerobic decomposition. Examples include food waste and garden waste as well as paper. Biodegradable wastes form part of household and ICI waste, or are separately collected.

Biowaste: Separate collected organic waste, especially from households

Bulky waste: Waste that due to its bulky character needs special consideration for its management. Examples are white goods, old furniture, mattresses, etc. Construction and demolition waste is not included.

Construction and demolition waste ("C&D Waste"): Rubble and other waste material arising from the construction, demolition, renovation or reconstruction of buildings; consists mainly of building material and soil, including excavated soil. C&D waste is generated from all economic activity sectors.

Dry Recyclables: All recyclable materials except organic waste. Dry recyclables include glass, textiles, packaging, paper.

Green waste: Green waste is the sum of all organic waste that is generated at green areas such as private gardens and public parks. It includes grass clippings, leaves etc. that is able to be recovered. Green waste forms part of the household and ICI waste or is separately collected.

Hazardous waste: Hazardous waste requires special handling and disposal practices due to its endangering character for people, the environment, and equipment or recovery products; e.g. waste oils, (car) batteries, paints, chemicals. In households it refers to all hazardous waste generated usually in small amounts. Included are e.g. pesticides, oil- and solvent-laden substances, paint, lacquer, disinfectants, wood preserver, chemical residues, batteries, fluorescent tubes, acids and bases.

Healthcare waste: In a common split-up healthcare waste (often also designated as medical waste) is differentiated into four groups depending on its hazardous properties:

1. Non-hazardous: These compounds are similar to those arising in households e.g. MSW, recyclables, biological waste.
2. Wastes with medical risks for persons coming into contact with the waste: This comprises typical medical products, contaminated with blood, urine or other body liquids.
3. Wastes with high infection risk (epidemiological threat): This waste contains contaminated material of defined diseases.
4. Wastes with other risks (environmental, toxicological, etc.): This group comprises all other materials to be discarded of arising from hospital operations (e.g. electronic apparatus, cleaning and disinfecting agents, medicines, oil, paints, ...)

Household waste: Waste from households as well as other waste, which, because of its nature or composition, is similar to waste from households, e.g. waste from shops being co-collected with household waste.

Industrial, Commercial and Institutional waste ("ICI Waste"): Waste that is generated in different economic sectors and institutions (schools, household similar waste from hospitals, government buildings), if it can be treated like household waste.

Mining waste: Soil, sand, rock, stones, from recovering mineral resources. Compared to other wastes mining waste is generated in very high amounts. In general mining wastes do not have no severe toxic impacts to the environment. Usually the management of mining wastes is outside the responsibility of municipalities.

Municipal solid waste (MSW): Municipal solid waste includes almost (!) all dry wastes created in a municipality, such as

- Household waste
- Industrial, commercial and institutional waste

- Bulky waste
- Green waste
- Public service waste
  - Fractions collected separately for recovery operations

  - Hazardous waste

Usually excluded from MSW are sewage sludge, construction and demolition waste, agricultural and mining waste.

Public service waste: Waste from selected municipal services, i.e. waste from maintenance of parks and gardens, waste from street cleaning services (street sweeping, content of litter containers, market-cleansing waste).

Recyclables: Recyclables comprise all components which are presently sourced from MSW (or even other waste streams as e.g. C&D waste) and transferred to industries utilizing it as secondary raw material, or secondary fuel (not individually shown in Fig. 1).

Sewage sludge: Sludge from wastewater treatment. This includes sludge generated by municipal wastewater treatment plants as well as by private treatment plants, e.g. within manufacturing industries.

Waste: Waste are materials for which the generator has no further use for own purpose of production, transformation or consumption, and which he discards or is required to discard. Wastes may be generated during the extraction of raw materials, during the processing of raw materials and after the consumption of final products.

The above classification represents almost the most simplified set of definitions for waste. For the exact definition of a single waste type, a much more detailed listing would be required, in order to clearly outline the requirements for collection, treatment, approvals and the like. In EU regulations the "European Waste Catalogue" comprises 20 groups with a several hundreds of single waste sorts.

Fig. 2: Various types of waste, clockwise from top left: Municipal waste, bulky waste, commercial / industrial waste (with integrated bacon production), biowaste, green waste

1.2. Levels of Responsibilities

Responsibility for waste management can broadly be broken up into two areas: the *legislative* area, meaning all applicable laws and ordinances on how to avoid, recycle, transport, treat and dispose the different kind of wastes, and the *executive* area, meaning the institutions which are responsible for enforcing the regulations.

1.2.1. Legislative level

The legislative area is represented by the national parliaments which create the laws regulating the handling and management of waste. In almost any country, there is a basic law applicable to the item "waste", which sets general priorities, how to handle waste in a sustainable way, names the responsible institutions to take care for execution of the law, and defines approval conditions. This basic law is accompanied by several specific regulations for the different operations and measures e.g. relating to:

- the naming, registration and disposal control of waste
- the prescribed methods to handle the types of waste
- the technical equipment and emission protection measures for facilities treating and disposing waste
- minimum recycling proportions for different waste types.
- time schedules, setting targets when a specific recycling or treatment system or a reduction aim must be achieved.

This national legislative process is predominantly influenced by the EU-Regulations: Stemming from the overarching objective that all member states of the EU should ultimately reach the same standard in waste management; the EU-Commission sets two different types of regulations:

EU-Ordinance: This is a type of regulation, which has immediate effect in all member states *without any conversion or changes by the different nations* e.g. the ordinance how to treat animal bodies and meat residues

EU-Directive: This type of regulation sets *framework conditions* for different waste collection and treatment operations, which must be transferred into national law of the member states. The EU Directives provide some flexibility for member states to comply with framework conditions. The most prominent directive is the Waste Framework Directive 2006/12/EC, which sets the main priorities. Others are more specific and relate to particular systems and processes. For example the Incineration Directive does not mandate incineration, rather it sets minimum standards for flue gas quality *if* incineration is operated.

1.2.2. Executive level

In the executive area of responsibility for waste management, each country's National Ministry of Environment is the senior control institution, supervising the performance in the different regions of the country. Depending on the structure of the nation's administration, e.g. in a federal unit like the Republic of Germany, the (sub) states of the nation have their own specific legislation and waste management plans. The final responsibility for a waste management is in hands of the single communities (and cities), these forming management units of between about 100.000 inhabitants to some millions of inhabitants. From experience, these management units should not exceed about 200.000 inhabitants, since this is a reasonable size to install the components of a waste management system, especially centralized treatment and disposal units at an economic scale.

In hands of the responsible counties is not only the task *to plan, install and control* the waste management system in an appropriate way, but as well the right *to recover the costs of it by specific fees* being paid by citizens, enterprises and institutions.

Installation and operation of waste concept units can be done by the community itself, but as well given to private enterprises. This can be transferred - after a strictly regulated request for proposals - for collection, transport, recycling processes and final disposal. There is no objection against this procedure, as long as the private enterprises prove permanently their ability to do the job in a responsible way.

The share of responsibilities on community level in a practical sense - who is setting and collecting fees, where and how does the private sector get involved? - is described in more depth in next chapters.

1.3. Consequences of inadequate dealing with waste

In this section, inadequate dealing with waste refers to a behavior that disregards some basic aspects of waste management, such as *hygiene* to minimize disease; *separate collection* to minimize the pollutant content; *recovery* to preserve raw materials and energy; and *environmentally compatible disposal* to minimize the long- term effects of land filling.

As there are in some countries conditions that do not take into account all of these basic aspects the question could come up: "Why regulate waste management?" The answer is that *environment and health are public goods where free markets generally fail to provide equitable and sustainable long term solutions.*

1.3.1. Ecological impacts

The activities associated with waste from generation to final disposal can be divided into the following phases: storage and collection, transport, treatment and disposal. All of these phases cause environmental impacts to varying degree depending on the technical standards employed.

For storage and collection, hygiene issues are of great importance. Standards often reflect climatic conditions, e.g. in Southern European countries waste is usually collected at a higher frequency - daily or several times a week - compared to cooler regions - up to once every eight weeks in rural alpine areas for example.

A large number of impacts are influenced in particular by *waste disposal.*

Land filling is the traditionally chosen waste disposal solution as it is the cheapest. Land filling however pollutes drinking water resources and soil through uncontrolled leachate emissions from open dump sites. Air quality is affected by landfill gas which is emitted without any control and causes odor problems.

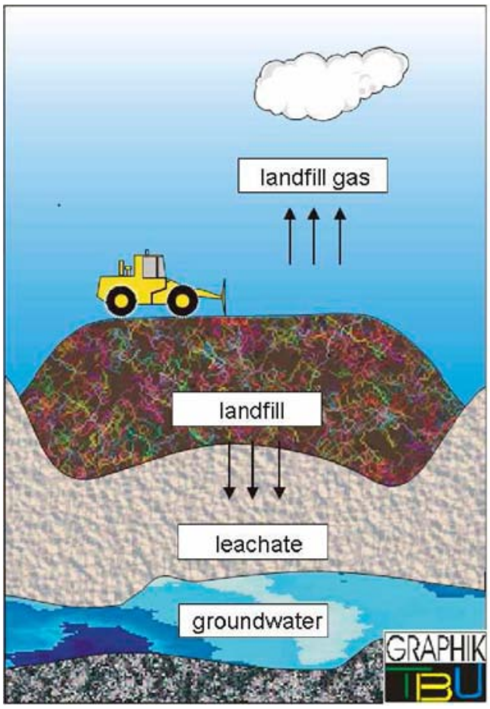


Fig 3: Emission paths of a landfill

Leachate is the solution resulting from leaching of soluble constituents from waste in a landfill through downward (and sideways) percolation of water. The environmental risk of leachate lies mainly in the possible contamination of surrounding surface water, groundwater and subsoil. Leachate quantity is influenced by precipitation, and its contamination is mainly affected by organic material in the waste. When digested without oxygen (which is largely absent inside a landfill), organic compounds convert to a set of diluted substances. In addition the resulting organic acids dilute heavy metals from other waste components and convey them to the groundwater underneath the landfill. In parallel, toxic organic compounds such as oil, pesticides, and industrial residues find their way out of corroding barrels. Leachate emissions continue for much longer than the operating period of the landfill, typically for several decades after closing the landfill.

The organic components in the landfill-body also decompose to form **landfill gas,** analogous to an anaerobic biological reactor. The landfill gas consists mainly of methane and carbon dioxide. One tone of waste typically produces approximately 250 m^3 of landfill gas.

Methane is the landfill gas component of most environmental relevance. After carbon dioxide it is the second-biggest contributor (19%) to global warming. Methane is 21 times more powerful a greenhouse gas than CO2. Methane emissions from waste- disposal operations represent between 8% and 18% of the total methane emissions on earth.

1.3.1.1. Air pollution

Landfill gas composition and effects

Landfill gas is generated through the degradation of organic waste by microorganisms. The quality of the gas depends on the composition of the waste, presence of oxygen and temperature. Aerobic conditions lead to predominately CO_2 emissions. In anaerobic conditions, as is typical of landfills, methane and CO_2 are produced in equal amounts.

MORE:

Landfill gas also contains varying amounts of nitrogen, oxygen, water vapour, hydrogen sulphide, and other contaminants. Most of these other contaminants are known as "non-methane organic compounds". Some inorganic contaminants (for example mercury and tritium) are also known to be present in landfill gas. The non-methane organic compounds usually make up less than one percent of landfill gas. In 1991, the US EPA (United States Environmental Protection Agency) identified ninety-four non-methane organic compounds including toxic chemicals like benzene, chloroform and vinyl chloride.

Some examples for effects of pollutants:

Nitrogen dioxide (NO2)

Nitrogen dioxide reacts with sunlight and other hydrocarbons to form ozone. In the outer atmosphere ozone is of great benefit as it very effectively blocks harmful UV rays from the sun which cause cancer. However, this gas at ground level irritates the lungs which can affect respiration. So part of our activity on this planet destroys the good ozone (high up) while another creates bad ozone. NO_2 by itself can also affect respiration and bring on asthma in children.

Nitrogen oxides and sulphur dioxide (NOx and SO2)

Nitrogen oxides and sulphur dioxide can mix with water droplets in the atmosphere, creating acids. These can be blown a great distance from the source of the emission and fall as rain, harming soil, eroding buildings and entering freshwater supplies. Large areas of forest have been destroyed as a result of this acid rain.

Carbon monoxide (CO)

Carbon monoxide is a toxic gas and one that interrupts the take-up of oxygen by haemoglobin in the blood. The CO attaches more easily to the haemoglobin depriving the body of oxygen, causes rapid deterioration of cells and in high enough concentrations leads to death.

Carbon dioxide (CO2)

Carbon dioxide is one of the key greenhouse gases. Because human activities since the industrial revolution have rapidly increased concentrations of atmospheric carbon dioxide, it plays a major role in global warmingand anthropogenic climate change. It is also a major source of ocean acidification since it dissolves in water to form carbonic acid, which is a weak acid as its ionization in water is incomplete.

Hydrogen sulfide (H2S)

Hydrogen sulfide is a broad-spectrum poison, which can affect several different systems in the body, although the nervous system is most affected. It forms a complex bond with iron in cells, thus preventing cellular respiration.

Benzene (C6H6)

Benzene is an organic chemical compound.
Benzene increases the risk of cancer and other illnesses. Benzene is a notorious cause of bone marrow failure. Benzene targets liver, kidney, lung, heart and the brain and can cause DNA strand breaks, chromosomal damage, etc.

Chloroform (CHCL3)

Chloroform is an organic colorless, sweet-smelling, dense liquid compound and is considered somewhat hazardous. Several million tons are produced annually as a precursor to Teflon and refrigerants, but its use for refrigerants is being phased out. Chloroform has a multitude of natural sources, both biogenic and abiotic. It is estimated that greater than 90% of atmospheric chloroform is of natural origin. The US National Toxicology Program's twelfth report on carcinogens implicates it as reasonably anticipated to be a human carcinogen. It has been most readily associated with hepatocellular carcinoma.

"Substances Listed in the Twelfth Report on Carcinogens". Retrieved 2012-05-21.

Vinyl chloride (H_2C:CHCl)

Vinyl chloride is the organochloride. It is also called vinyl chloride monomer (VCM) or chloroethene. This colorless compound is an important industrial chemical chiefly used to produce the polymervinyl chloride (PVC).About 13 billion kilograms are produced annually. Vinyl chloride is a gas with a sweet odor. It is highly toxic, flammable, and carcinogenic.

Waste treatment

For environmental reasons, the acidic aqueous waste stream is treated to remove organic compounds and neutralized before it can be sent to the plant's "outfall". An outfall is a monitored wastewater stream that must conform to the plant's standards. Some very hazardous wastes are generated in the recovery of the product vinyl chloride. These wastes require specialized procedures. These wastes are burned onsite in hazardous waste burners that again are subject to strict standards.

Landfill gas use

The gases produced within the landfill can be collected and flared off or used to produce heat or electricity. For example the city of Sioux Falls, South Dakota installed a landfill gas collection system which collects, cools, dries, and compresses the gas into an 11-mile pipeline. The gas is then used to power an ethanol plant. Pipelines transmit gas to boilers, dryers, or kilns, where it is used much in the same way as natural gas. Landfill gas is cheaper than natural gas and holds about half the heating value at 16,785 – 20,495 kJ/m3 (450 – 550 Btu/ft3) as compared to 35,406 kJ/m3 (950 Btu/ft3) of natural gas. Direct use of the gas is usually within 8.0 km of the landfill.

The number of landfill gas projects in USA, which convert the methane gas that is emitted from decomposing garbage into power, went from 399 in 2005, to 594 in 2012 according to the Environmental Protection Agency (USA). These projects are popular because they reduce greenhouse gas emissions. These projects collect the methane gas, and treat it for electricity or upgraded to pipeline-grade gas. These projects power homes, buildings, and vehicles.

"Landfill Gas Control Measures". Agency for Toxic Substances & Disease Registry. Retrieved 2010-04-26.

"Landfill Gas to Energy". EPA. Retrieved 2012-07-29.

Landfill Gas Collection

Landfill gas is gathered from landfills through extraction wells. A typical gas extraction well is shown in figure 4.

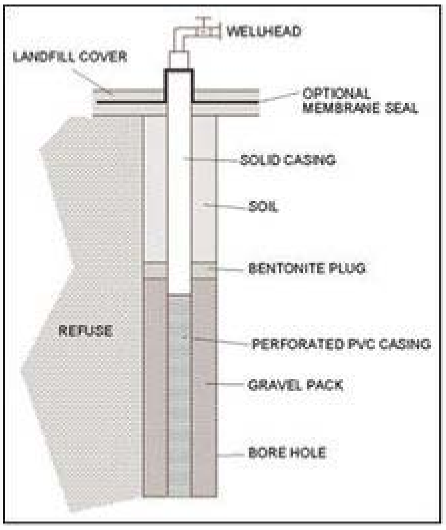


Fig. 4: Gas extraction well.

U.S. Environmental Protection Agency. "Project Technology Options." LFG Energy Project Development Handbook. 9 Sept. 2009. Web. 26 Nov. 2009.
<http://www.epa.gov/lmop/res/handbook.htm>/.

Fig.5. Landfill gas is extracted and piped to a main collection header, where it is sent to be treated or flared.

www.window.state.tx.us

Landfill Gas Treatment

Landfill gas must be treated to remove pollutants. The treatment system depends on the end use. Minimal treatment is needed for the direct use of gas in boiler, furnaces, or kilns. Using the gas in electricity generation typically requires more in-depth treatment.

MORE:

Treatment systems are divided into primary and secondary treatment processing. Primary processing systems remove moisture and particulates. Gas cooling and compression are common in primary processing. Secondary treatment systems employ multiple cleanup processes - physical and chemical, depending on the specifications of the end use.

1.3.1.2. Soil pollution

Soil pollution has a different origin:

Dumping of solid waste
Seepage from a landfill and solid waste can affect the soil and polluted it with heavy metals, solvents, different toxins.

Solid waste includes garbage, domestic refuse and discarded solid materials from commercial, industrial and agricultural operations. They contain increasing amounts of paper, cardboards, plastics, glass, old construction material, packaging material and toxic or otherwise hazardous

substances. Since a significant amount of urban solid waste tends to be paper and food waste, the majority is recyclable or biodegradable in landfills. Similarly, most agricultural waste is recycled and mining waste is left on site.
The portion of solid waste that is hazardous such as oils, battery metals, heavy metals from industries are the ones we have to pay particular attention to. More than 90% of hazardous waste is produced by chemical, petroleum and metal-related industries and small businesses such as dry cleaners and gas stations contribute as well.

Pollution from urbanization

The urban waste can cause:

Pollution of surface soils

Urban activities generate large quantities of city wastes some of which are biodegradable materials (like vegetables, animal wastes, papers, wooden pieces, plant twigs, leaves, cloth wastes) and many are non-biodegradable materials (such as plastic bags, plastic bottles, glass bottles, stone / cement pieces). If they left uncollected and decomposed, they can cause many problems:

- Clogging of drains: It causes serious drainage problems including the burst / leakage of drainage lines which leading to health problems.
- Barrier to movement of water: Solid wastes have seriously damaged the norm movement of water thus creating problem of inundation, damage to foundation of buildings as well as public health hazards.
- Foul smell: Generated by dumping the wastes at a place.
- Increased microbial activities: Microbial decomposition of organic wastes generate large quantities of methane and other gasses.
- If the solid wastes are hospital wastes they create many health problems as they may have dangerous pathogens, medicines, injections.

Pollution of underground soils

Many dangerous chemicals like cadmium, chromium, lead, arsenic, selenium products are likely to be deposited in underground soil. They can damage the normal activities and ecological balance in the underground soil.

Underground soils can be polluted by:

- Chemicals released by industrial wastes and industrial waters
- Decomposed and partially decomposed materials of sanitary wastes
- Runoff from pollutants (waste residue, rotting organic material) leaching out of landfill
- Acid rain (fumes from open burning, landfill gas components, mixing with rain)
- Sewage discharged into rivers instead of being treated
- Injection into groundwater as a disposal method
- Septic tank seepage
- Lagoon seepage

• Sanitary/hazardous landfill seepage
• Scrap yards
• Leaks from sanitary sewers

Control of soil pollution – regular measurement of physical, chemical and biology soil properties

http://www.youtube.com/watch?v=q95QDKLU38g

1.3.1.3. Water pollution

Water pollution occurs when waste pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds.

Fig.6.Raw sewage and industrial waste in the New River as it passes from Mexicali to Calexico, California

http://www.calexiconewriver.com/media.php

Domestic households, industrial and agricultural practices produce solid waste and wastewater that can cause pollution of seas, lakes and rivers:

- Sewage often contains faeces, urine and laundry waste. Sewage is mainly biodegradable and most of it is broken down in the environment by microbes.
- Sewage disposal is a major problem in developing countries as many people in these areas don’t have access to sanitary conditions and clean water.
- Untreated sewage water in such areas can contaminate the environment and cause diseases such as diarrhoea.
- Sewage is treated in water treatment plants and the waste is often disposed into the sea.

- In developed countries, sewage often causes problems when people flush chemical and pharmaceutical substances down the toilet. When people are ill, sewage often carries harmful viruses and bacteria into the environment causing health problems.
- Food processing waste often can includes oxygen-demanding substances, fats and grease
- Tree debris from logging operations can contaminate the enviroment.

http://www.water-pollution.org.uk/sewageandwastewater.html

Fig.7.Muddy river polluted by industrial sediment.
Photo courtesy of United States Geological Survey.

Fig.8. A garbage collection boom in an urban-area stream in Auckland, New Zealand.
http://en.wikipedia.org/wiki/File:Garbage

MORE:

The water contamination leads to changes such as elevated temperature and discoloration. Some waste component may cause turbidity (cloudiness) which blocks light and disturb animal, microbial and plant growth. Pollutants change water's physical and chemical parameters also - acidity (change in pH), electrical conductivity, and provoke eutrophication. Eutrophication is an increase in nutrients in water and following massive production of algae – "algal bloom". Depending on the degree of eutrophication, subsequent negative environmental effects such as anoxia (oxygen depletion) and reductions in water quality may occur, affecting fish, other animal populationsq microbes and water plants. Many of the contaminants are toxic. Pathogens in waste can produce waterborne diseases in either human or animal hosts.

Fig.9.Eutrophication

http://en.wikipedia.org/wiki/File:Water_pollution.jpg

Monitoring of water quality

Water pollution can be analyzed through different methods: physical, chemical and biological. Some methods may be conducted *in situ,* without sampling, such as temperature. WHO (World Health Organization) and Government agencies have published standardized, validated analytical test methods to facilitate the comparability of results from disparate testing events.

http://www.youtube.com/watch?v=cC8-Mhp_RJU

Fig.10. Environmental scientists preparing water autosamplers.
(www.agron.iastate.edu)

Another critical element is the **open burning** of waste during collection or at landfills in order to reduce volume and/or provide better access to scrap metal. This "casual thermal treatment" causes a considerable negative impact on air quality (e.g. high levels of dioxins are released under such conditions).

1.3.2. Physical impacts

In many countries "scavenging" (searching for recyclables during waste collection and/or disposal, and to herd animals on landfills) is still a common practice. Consequences of this activity include:

- People working without any means of personal protection have a reduced life expectancy.
- Treatment of diseases results in high costs.
- Contaminants enter the food chain (milk, meat).

Fig. 11.: Herding of cattle on the landfill of a South East European capital city

The main technical requirements for household waste collection are regularity of service, certain work protection measures for collection staff (gloves, good visibility in order to avoid traffic accidents), and closed vehicles (to avoid emission of dust and odour).

Waste reduction and separation, as well as appropriate treatment and disposal must be included in waste management activities for a number of reasons. Examples are:

- *Hygiene aspects* are dependant on waste collection and disposal conditions. Unsuitable methods such as open storing within the city increase exposure to illness. High costs for

Fig. 12.: Example of unsuitable handling of waste

Fig. 13.: Example of the "oriental button"

- medical treatment and disinfection chemicals are incurred. Far more effective are preventative measures through appropriate waste handling.
- *Prevention of injuries* due to unsuitable handling of waste. In particular, clinical waste (and general waste) causes hazards to the health institution personnel as well as to collection staff. Once disposed, the waste affects on-site scavengers.
- *Prevention of accidents* on dumping sites is an issue of high priority amongst the proposed measures. The current situation presents several dangers, especially to scavengers on open, uncontrolled dumping sites.

One of these is leishmaniosia tropica (oriental button"), which is transmitted to humans by the sand fly. This species incubates in warm and dark places such as livestock stables, sewers or ponds of waste leachate. One of the consequences of *unsuitable handling of waste* is the advancement of particular diseases.

Fig. 14.: Example of inefficient disinfection of waste in Anatolia, May 2000

Health concern due to improper management can not only be found in the Eastern parts of Turkey for example, but also in 'Old Europe'.

Fig. 15.: Breakdown of waste collection in Naples / Italy, May 2007

The practice of *spreading chemicals* on the surface of the waste is on the one hand very inefficient and requires large amounts of disinfectants, and on the other hand causes serious problems to health and the environment.

1.4. Waste minimization

Waste minimization is the policy of reducing the waste produced by a person or a society.

How waste minimization can done?

● Using more efficient manufacturing processes
● Using better materials
● Application of waste minimization techniques that led to the development of innovative and commercially successful replacement products.

MORE:
Such processes can be realized through:

●Resource optimisation
For example, a dressmaker may arrange pattern pieces on a length of fabric in a particular way to enable the garment to be cut out from the smallest area of fabric.
●Reuse of scrap material
Scraps can be immediately re-incorporated at the beginning of the manufacturing line so that they do not become a waste product. Many factories routinely do this. For example,

paper plants return any damaged rolls to the beginning of the production; in the manufacture of plastic items, off-cuts and scrap are re-incorporated into new products.

●Quality control and process monitoring

Steps can be taken to ensure that the number of reject batches is kept to a minimum. This is achieved by number of inspection and the number of parameters of inspection. For example, installing automated monitoring equipment can help to identify the problems at an early stage.

●Waste exchanges

This is where the waste product of one process becomes the raw material for a second process. Waste exchanges represent another way of reducing waste disposal volumes for waste that cannot be eliminated.

●Ship to point of use

This involves making deliveries of incoming raw materials or components direct to the point where they are assembled or used in the manufacturing process to minimise handling and the use of protective wrappings or enclosures.

Miniwaste is a European project (January 2010 – December 2012), co-funded by the LIFE+ programme of the European Commission. It is designed to “bring bio-waste back to life”. In other words, it is intended to demonstrate that it is possible to significantly reduce the amount of bio-waste at a local level.

The project emphasizes the efficiency and sustainability of bio-waste reduction actions at source, in particular by organizing demonstration actions and trainings for the population, and by offering a better way of evaluating and controlling waste prevention.

Sources: Miniwaste website ACR+ - Miniwaste project presentation

1.5. PR work of communities to increase “waste awareness

This training material deals with the management of waste generated by citizen. Regard-less of which technical solutions is adopted to collect, treat, recover, recycle or dispose of MSW, the critical factor in the success of programs and in meeting the main EU objectives is the active participation of people, because they are the first element of the chain.

Fig. 16. shows a postcard issued for free by the municipality of Vienna / Austria. The postcard is part of a series (all of them are still subject to clarify the copyright issue) intended to focus people on waste in everyday life and influence behaviour. In this postcard below rubbish is represented by a green creature. The message of the postcard is: Do not throw food away - that people should plan their shopping and consumption patterns so that food wastage is minimized.

Fig. 16. Vienna postcard: Do not discard unconsumed food

Governments have the responsibility to provide a comprehensive waste management system, but every chosen system will fail, if the affected citizens don't participate. Therefore a priority for the governments is to increase the people's "awareness of waste". The message in Fig. 17 is: "Rubbish! Now you're due!"

Fig. 17. Example of a postcard from the municipality of Vienna / Austria

The main behavioral objective is for citizens to prevent waste and to participate in provided systems, e.g. separate collection. In the end it is a question of common social value. Some methods of waste prevention require us to change our purchasing and consumption patterns,, in many instances this is contrary to industry and business objectives which promote high consumption and rapid turnover. Fig. 18. shows an example from Poland intended to remind and motivate the people to participate in separate collection systems.

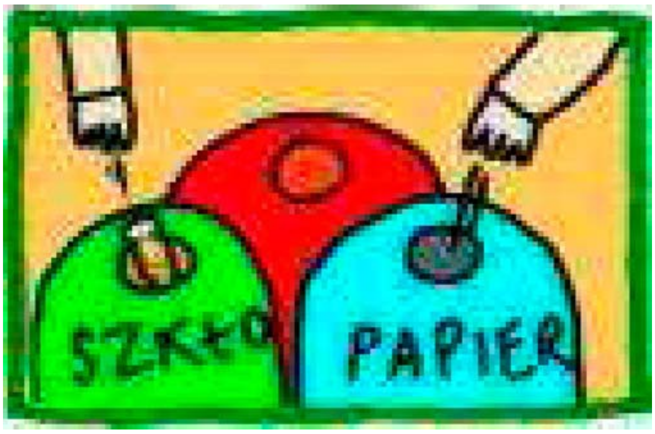


Fig. 18. Example from Poland to participate in separate collection

Economic development has led to a "disposable society". Goods are made to be used and thrown away afterwards.

Against this should be placed stability, longevity and quality as common worth. Everyone might know the experience that "the one who buys cheap buys double". This means that in the end it is cheaper in the long term to buy one more expensive product of higher quality and a longer life, than two or three cheaper products over the same period.

In addition, in general more expensive products are often able to be repaired, which further increases product life lifetime and prevents waste.

Fig. 19. deals with this aspect by saying: "My bicycle is not rubbish!" This is intended to motivate citizens to repair things instead of discarding them.

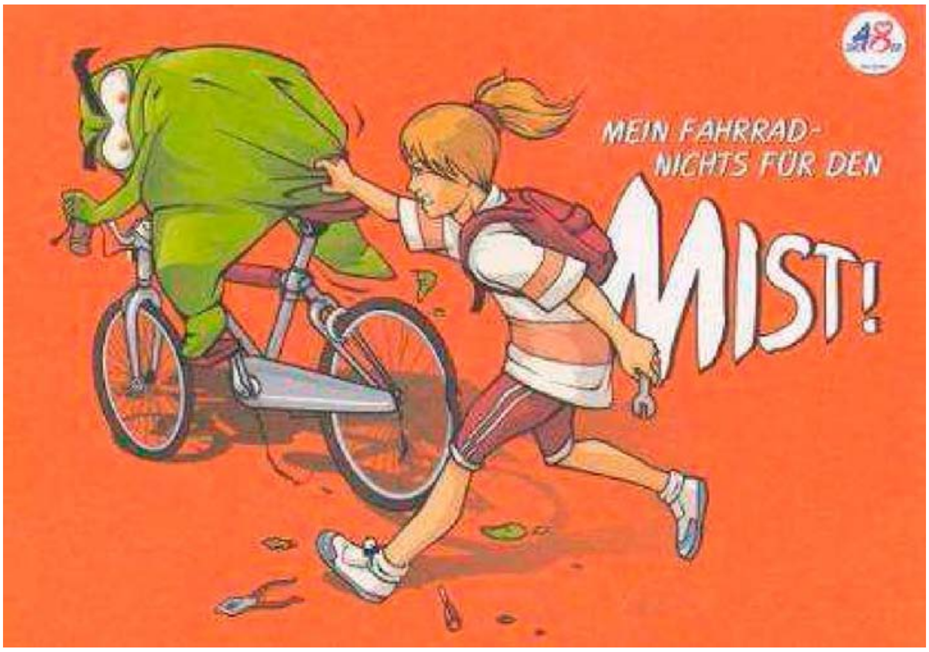


Fig. 19. A postcard from Vienna / Austria that says to repair is better than to discard

Another issue is to look for regional products when purchasing goods. This requires less transport and therefore less packaging which, in turn, reduces waste. Additionally some people recognise that to *use* something can be cheaper than to *own* it. That means that renting can be a good option for many things. In urban areas e.g. car-sharing is a good alternative to buying a car.

The question for the municipalities is how to achieve this increase of "waste awareness"? For this a variety of possible measures can be employed to target different parts of society.

The key word to reach this goal is *information.* People can be informed through the media, newspapers or personal contact. But to inform might not be enough. To induce awareness and motivation for the environment, especially for waste, consideration could be given to adopting successfully applied method in advertising and sensationalist media which entertain while informing, i.e. *infotainment.* To raise interest the events, actions or measures should have catchy titles. For this *'plays on words'* have proven successful. The following media can be used:

- Radio
- Television
- Internet

Successful examples are radio spots, TV-spots and interesting web pages that can be adapted to each target group.

Other possible actions are street parties. During such events leaflets, flyers or other information material like the postcards shown here can be disseminated. Lotteries can be provided as well as posters and sticker as giveaways. Campaigns might have a mascot that represents the main ideas of the measure.

Fig. 20. seeks to instruct how to correctly collect packaging waste, especially PET bottles. The text is a German play on words that says: "To meet the bin".

Fig. 20. Example of a postcard to collect packaging waste correctly

All these initiatives should inform, clarify and motivate the people to participate in the waste management system. Another important target group is school children. At schools events such as performances that deal with waste can be initiated. Other possibilities are to make "waste weeks" with special projects developed by the children. In this way future generations grow up with a natural awareness of environment and how to handle waste in an environment-friendly way. This is the most sustainable way to reach a highly developed level of waste management.

2. Chapter 2. WASTE GENERATION

Waste represents an enormous loss of resources in the form of both materials and energy. The amount of waste produced can be seen as an indicator of how efficient we are as a society, particularly in relation to our use of natural resources and waste treatment operations.

The reason why the quantities of solid waste generated are important to know is that they are the basis for the development of a waste management system. Solid waste quantities should be measured in weight terms, because the volume itself is meaningless without the knowledge of density, which is very complicate to measure.

2.1. Total waste

Total waste represents the quantity of waste originating from production, represented by sectors of economic activity, and from consumption, represented by municipal waste.

Waste generation in EU 25 is estimated at about 1.3 billion tons in 2002. The amount can only be estimated, because data on total waste generated are incomplete. The estimated amount excludes waste from agriculture, forestry and fishery, from mining and quarrying, and from the service and public sector. For these sectors a valid estimate is currently not possible.

2.2. Municipal waste

Following the definition given in chapter 1 municipal solid waste includes almost (!) all *dry* wastes created in a municipality, such as household waste, industrial, commercial and institutional waste, bulky waste, green waste, public service waste, fractions collected separately for recovery operations and hazardous waste.

Usually excluded are sewage sludge, construction and demolition waste, agricultural and mining waste.

Municipal waste is currently the best indicator available for describing the general development of waste generation and treatment in European countries, because all countries must collect data on municipal waste. Data coverage for other waste fractions, for example total waste or household waste, is more limited.

Municipal waste constitutes only around 18 % of total waste generated, but due to its inhomogeneous character and its distribution among many waste generators, environmentally sound management of this fraction is complicated. Municipal waste contains many materials for which recycling is environmentally beneficial.

The generation of municipal waste per capita in Western European [1] countries continues to grow while remaining stable in Central and Eastern European [2] countries.

The average amount of municipal waste generated per capita per year in many Western European countries has reached more than 500 kg.

One of the targets set by the EU was to reduce the generation of municipal waste per capita per year to the average 1985 EU level of 300 kg by the year 2000 and then stabilise it at that level. The indicator (Fig. 21.) shows that the target is far from being reached.

[1] Western European countries are the EU-15 countries + Norway and Iceland.
[2] Central and Eastern European countries are the EU-10 + Romania and Bulgaria.

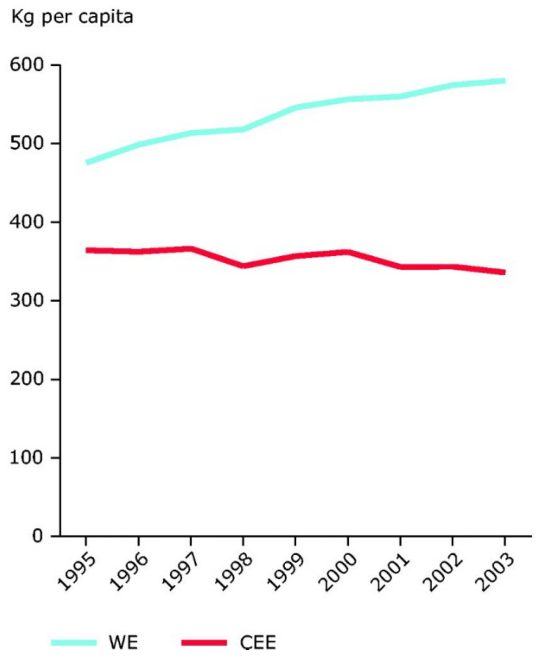


Fig. 21. Municipal waste generation in Western European (WE) and Central and Eastern European (CEE) countries ["The European environment - State and outlook 2005" published by the European Environment Agency (EEA)]

Municipal waste generation rates in Central and Eastern Europe are lower than in Western European countries and generation is decreasing slightly. Whether this is due to different consumption patterns or underdeveloped municipal waste collection and disposal systems needs further clarification. Reporting systems also need further development.

Fig. 16 shows annual municipal waste generation in the EU 25 in kg per capita since 1995. In the figure a base of 100 has been set in the reference year of 1995. Also shown is the corresponding growth in GDP for EU 25 during the same period. There is a noticeable connection between the economic growth and the municipal waste generation.

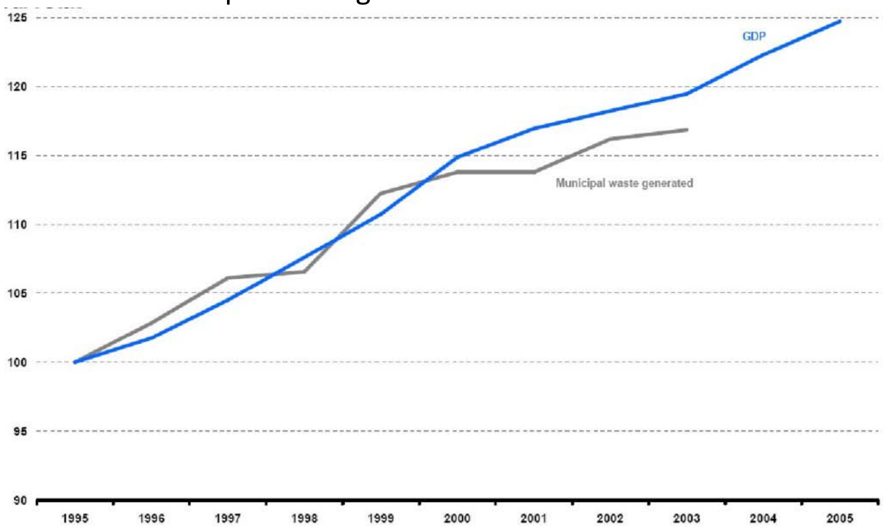


Fig. 22. Municipal waste generated (EU-25) kg per capita (index 1995 = 100) [Eurostat.]

The data on generation and treatment of municipal waste are measured against an indicator set developed for municipal waste. The municipal waste indicators are part of the structural indicators designed to measure the success or failure of EU policies on an annually basis. The set consists of the three indicators: 'municipal waste generated', 'municipal waste landfilled' and 'municipal waste incinerated', expressed as amount in kg per person and year.

Fig. 23. presents the development of municipal waste generation and treatment for EU 25 from 1995 to 2003. The graph shows that municipal waste generation in this period has constantly been growing.

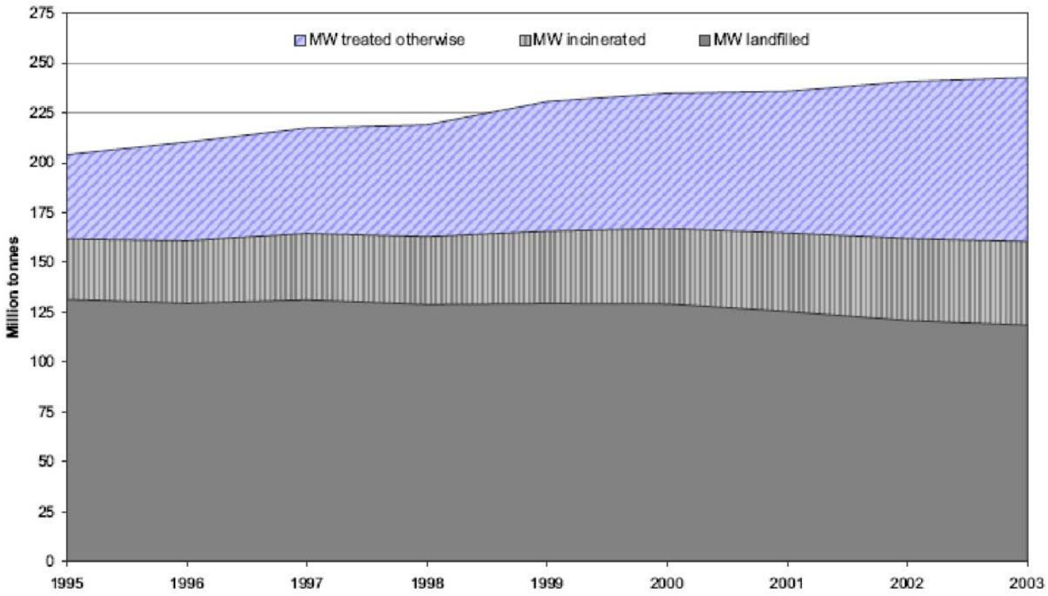


Fig. 23. Generation and treatment of municipal waste in EU 25 from 1995 to 2003 (Million tons) [EUROSTAT, Waste generated and treated in Europe, 2005 Edition]

Landfilling is still the main option for the disposal of municipal waste. In 2003, nearly half of the total generated waste was landfilled. The landfilled totals have shown a slight but constant decrease in recent years. This is the result of increased separate collection and recycling, and of the steady rise of incineration (thermal treatment and energy recovery).

Incineration has increased in the reference period and accounts 17 % of the treated waste. Recycling and other treatment operations have nearly doubled in the same time.

The comparison of old and new Member States in Fig. 24. shows that the overall growth of municipal waste generation results from the development in the old EU Member States. Waste generation increased in EU 15 by 23 % within the reference period. In contrast, the trend in the new Member States is decreasing.

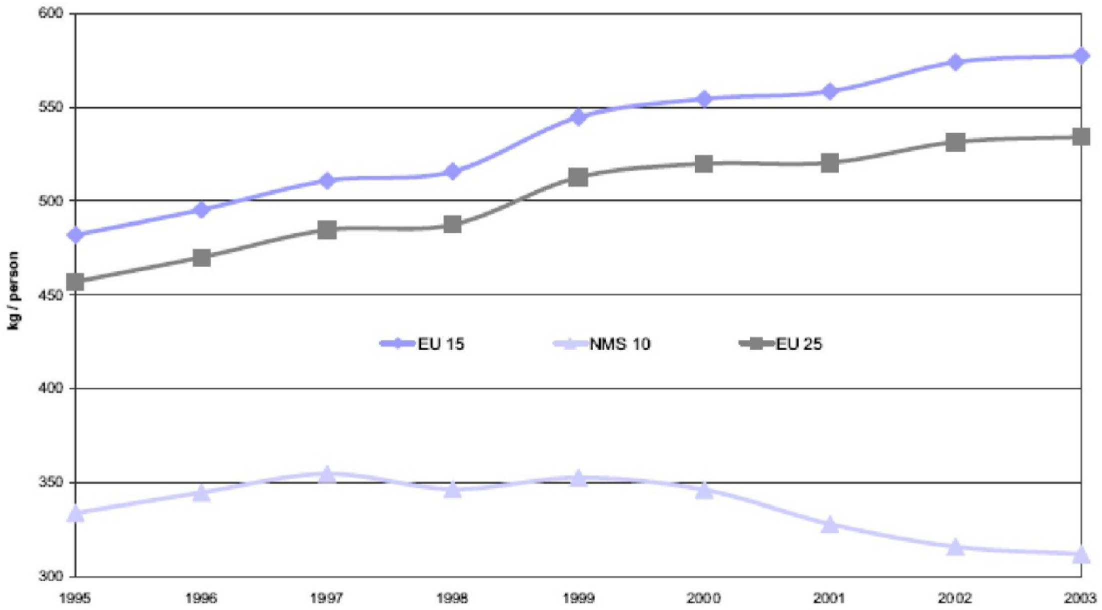


Fig. 24. Generation of municipal waste in the European Union from 1995 to 2003 (kg/person) [Eurostat, Waste generated and treated in Europe, 2005 Edition]

2.3. Composition of MSW

The composition of MSW depends on a range of variables including dwelling structure, season, existing waste management systems, behaviour of citizens, heating systems, etc. A method to analyse the composition of MSW is to sort it in several fractions followed by weighing of each fraction. The result can be shown in a pie chart.

Care must be taken when interpreting pie charts that illustrate fractions in percentages, since *proportions* are often misread as absolute *quantities* If e.g. in region A the percentage of organics in waste is 30 % and in region B 25 %, this does not mean that people of region A produce more organics in their waste. The problem of percentage and masses is shown in Fig. 25: It starts with an egg and two sausages on a table. Then a dog enters the room and leaves it after 5 minutes. During that period the percentage of eggs *increases* from 33 % to 50 % - the question is: "Has the dog laid an egg?" Of course not. The number of eggs doesn't change - the dog ate a sausage.

This simple example can be transferred to a waste management. Be aware that a percentage is only one side of the coin. If two percentages are compared the total amount must always be taken into consideration. A percentage can increase even though the total amount levels off or decreases.

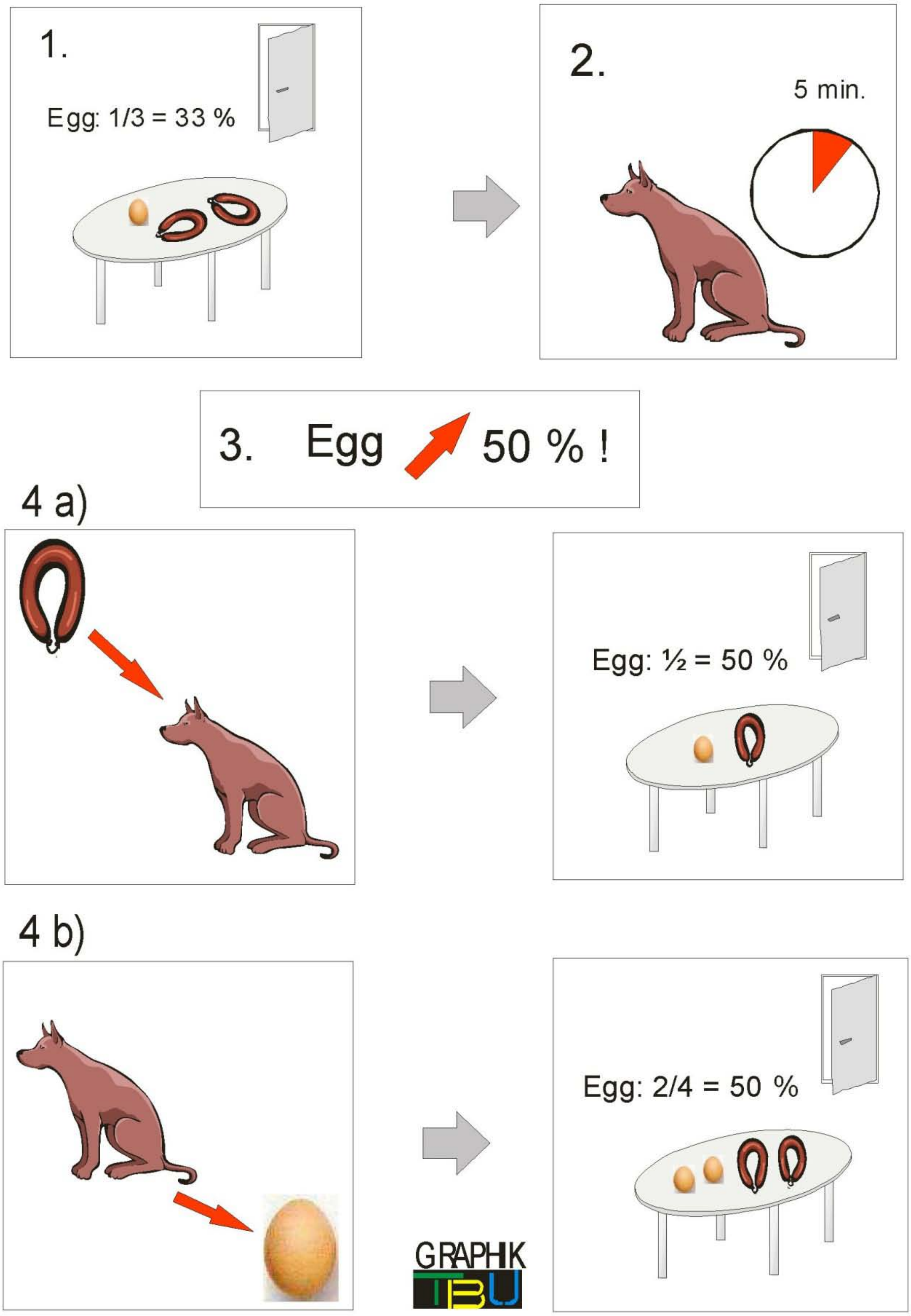


Fig. 25. The dog-egg-sausage-problem

The composition of MSW varies mainly depending on dwelling structure and season. For areas where dwellings with gardens are common, the MSW will include more grass and leaves than areas with high-rises and apartments. Additionally an area with combustion heating systems in every dwelling will result in MSW with higher ash content. Resource recovery systems should be designed taking account of these compositional variations. On the following pages examples of two different dwelling structures in Sofia / Bulgaria from 2006 are shown for winter and summer season.

Residential area:

Winter:

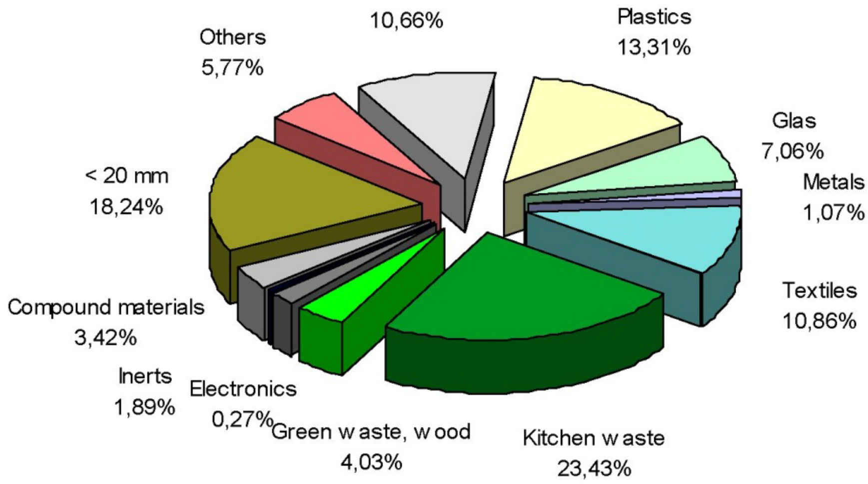


Fig. 26. MSW Composition, Sofia/Bulgaria 2006, residential area (winter)

Summer:

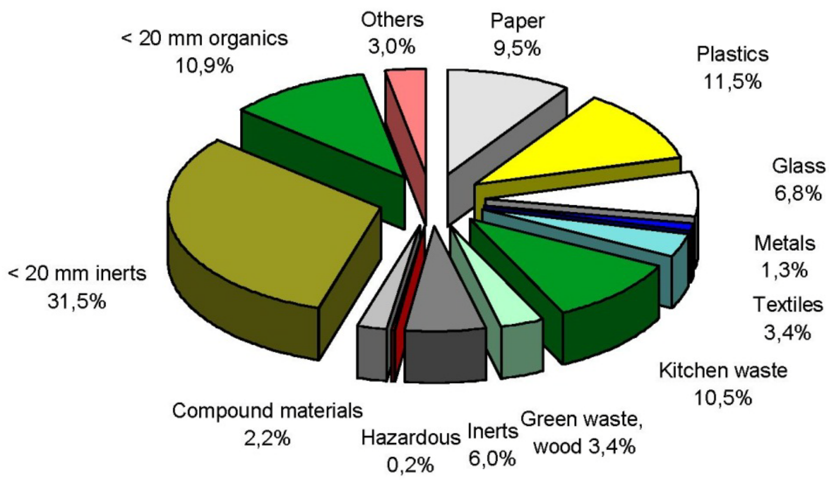


Fig. 27. MSW Composition, Sofia/Bulgaria 2006, residential area (summer)

Rural area:
Winter:

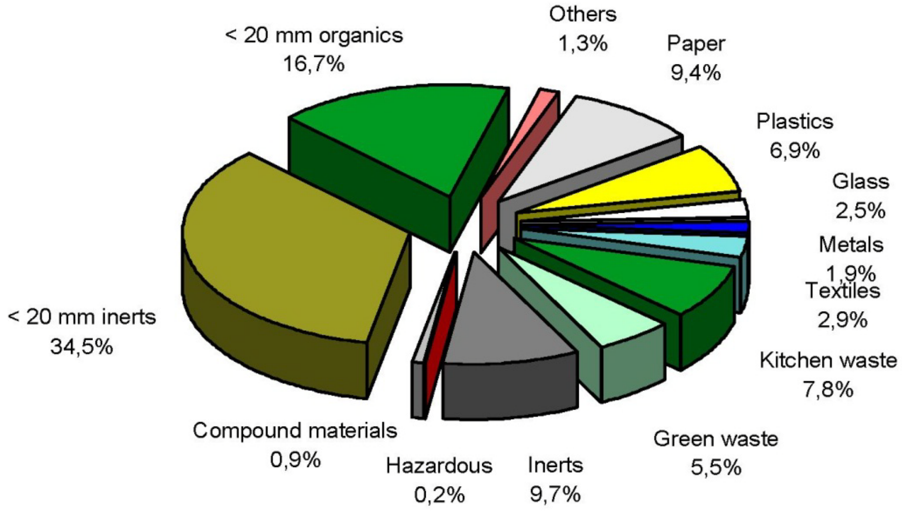


Fig. 28. MSW Composition, Sofia/Bulgaria 2006, rural area (winter)

Summer:

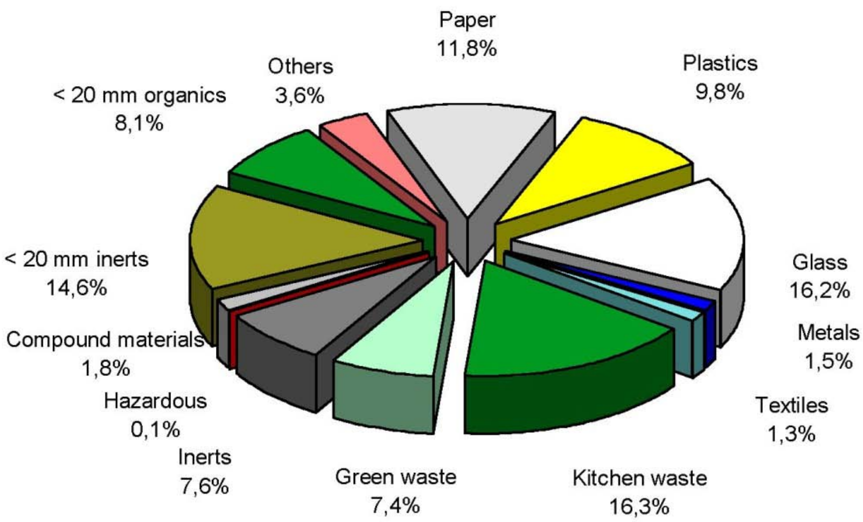


Fig. 29. MSW Composition, Sofia/Bulgaria 2006, rural area (summer)

2.4. Waste generation and management

The Waste Statistics Regulation aims: *'to establish a framework for the production of Community statistics on the generation, recovery and disposal of waste'.*

(Regulation on waste statistics (EC) No. 2150/2002, amended by **Commission Regulation (EU) No. 849/2010)**

Information on waste generation is split by source (several business activities according to the **NACE Rev. 2** classification and household activities) and by waste categories according to the European Waste Classification for statistical purposes (EWC-Stat).

http://ec.europa.eu/eurostat/ramon/nomenclatures/index

Information on waste treatment is split by treatment type (recovery, incineration with energy recovery, other incineration, disposal on land and land treatment) and by waste categories. All values are measured in tons of waste.

Additional metadata (information about the statistics) can be found **here:**

http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/env_wasr_esms.htm

The user should be aware that reporting under the Waste Statistics Regulation was revised in 2010 by Commission Regulation (EU) No. 849/2010). The improved reporting structure will be applied for the first time in 2012 (for reference year 2010). The key changes are as follows:

- Some new waste categories have been introduced and there has been a reorganisation of existing categories (e.g. mineral waste from construction, ferrous and non-ferrous metals, waste from waste treatment);
- The waste categories in Annex I (waste generation) and II (waste treatment) have been harmonised;
- A new treatment operation 'Backfilling' has been introduced, so the former category 'Recovery (excl. energy recovery)' will be split into 'Backfilling' and 'Recovery (excl. energy recovery and backfilling)';
- The treatment category 'Deposit onto or into land' has been regrouped: to harmonise this category with the definition of 'Landfilling' given in the Landfill Directive (1999/31/EC).

3. Chapter 3. WASTE COLLECTION AND REMOVAL

Regular waste collection systems are needed for three main reasons:		
	Measure	**Objectives**
1.	*Removal of pathogenic material from settlements.* This is based on previous experience that the spread of diseases such as Typhus or Cholera has been caused by the presence of organic wastes in the streets and thereby poor hygienic conditions for citizens.	Provision of public health and increase of common welfare.
2.	Avoidance of littering and illegal dumping.	Provision of an improved Aesthetic appearance of the cityscape.
3.	Only with a *regular and complete collection system* it is possible for a municipality to control the disposal of waste.	Provision of controlled dis-posal.

Table 1: Reasons for regular waste collection systems

These objectives are to be fulfilled whatever type of waste is collected. Therefore, at least in many of the bigger cities of Europe, regular waste collections have been in place since the end of the 19th century.

Fig. 30. System-free collection around 1900 [Mull-Handbuch, Nr. 2101 p. 6]

Waste collection systems can broadly be categorized according to four principal characteristics as follows:

- The timing of waste separation,
- The waste collection point,
- Technical waste removal systems, and
- Organisation of collections.

Each of these is discussed in the following sections.

3.1. Waste separation

Waste can be separated into the following: recoverable components; non-recoverable residual waste; and polluted products. Separation can take place either before collection on the waste generator side, or following the collection in a centralised sorting plant. These two different possibilities can also be combined with each other so that some secondary resources can be separated before collection, and others following collection.

Separation before collection	
Separation following collection	
Advantages	**Disadvantages**
+ Less expense on the waste generator side	- High sorting expense
+ Less expense at acquisition	- Low secondary resource quality
+ High capture rate	- Limited marketability
+ Possibility of recovery of numerous waste fractions	- High investment cost in sorting plants
	of space

Table 2: Advantages and disadvantages of separation before collection

Table 3: Advantages and disadvantages of separation after collection

3.2. Waste collection point

System options with differing collection points for wastes include:

> *Pick up system:* The provider of the refuse collection service picks up the waste at the property of the waste generator, irrespective of whether waste is separated into fractions or not.

> *Bring system:* The waste generator brings the waste to a central collection point.

Both systems can be applied in parallel (e.g. for certain waste fractions).

Pick up system	
Advantages	**Disadvantages**
+ High capture rate	- High investment costs for containers
+ High comfort for the user	- Low secondary resource quality
+ Availability of well-engineered containers	- Limiting on few relevant waste fractions
	- The use of several containers needs a lot of space

Table 4: Advantages and disadvantages of the pick-up system

Bring system	
Advantages	**Disadvantages**
+ Low investment costs for containers	- Low capture rate for secondary resources
+ High secondary resource quality	- High personnel costs at central collection points
+ High motivation of the participants	- Limited number of collection points
+ Possibility of separation in many fractions	- Possibility of mess at the central collection points

Table 5: Advantages and disadvantages of the bring system

Fig. **Fig. 31. Central collection point for the main waste streams in Vienna / Austria**

3.3. Waste removal

Waste removal systems comprise specially designed collection containers and vehicles. The following systems are usually applied:

- "empty the bin" systems,
- "change the bin" systems; and
- One-way receptacles (usually bags).

Bins for a single fraction (mono containers) or for several fractions (multi compartment container) can be used. Another possibility is the collection of waste without any technical removal system. This is called *system-free collection.*

System-free collection

System-free collections require waste to be picked up off the ground and lifted into collection vehicles by hand. This places high physical strain on collection personnel. Such collections are generally used for waste paper, scrap metal and bulky wastes. For residual waste, biowaste, waste glass and light packaging, system-free collection is not practicable because of the difficulty handling such wastes and inadequate hygienic and aesthetic conditions.

System-free collection	
Advantages	**Disadvantages**
+ No investments in containers	- Inadequate hygienic conditions for collection of residual waste, biowaste and light packaging
+ No special vehicles are required	- High physical strain for the collection personnel
	- Low collection rate
	- Difficult handling of loose waste

Table 6: Advantages and disadvantages of system-free collection

"Empty the bin" system

The "empty the bin" system employs standardised containers that are lifted up and emptied automatically into collection vehicles. For the collection of municipal solid waste and a high percentage of commercial waste with characteristics similar to MSW, the "empty the bin" system is highly suitable, as evidenced by the high profitability of such systems and the fact that bins are available in every form and size so that they fulfil all requirements of operational safety, hygiene and ease-of-use for both waste generator and collection personnel.

<table>
<tr><th colspan="2">"Empty the bin" system</th></tr>
<tr><th><u>Advantages</u></th><th><u>Disadvantages</u></th></tr>
<tr><td>+ High profitability</td><td rowspan="6">- Actually none, but in certain particular cases safety concerns apply (hiding place for explosives)</td></tr>
<tr><td>+ High ease of use</td></tr>
<tr><td>+ High operational safety</td></tr>
<tr><td>+ Good hygienic conditions</td></tr>
<tr><td>+ Offer of a variety of containers</td></tr>
<tr><td>+ Suitable for various intended uses</td></tr>
</table>

Table 7: Advantages and disadvantages of the "Empty the bin" system

Fig. 32. Examples of bins [http://www.atg-rosendahl.de/dienst/pics/umleer_kl.jpg]

Fig. 33. Example of a bin emptying vehicle [http://www.faun.com/faunkat/dbimg/x112_L.jpg]

"Change the bin" system

The "change the bin" system appears similar to the "empty the bin" system, but is technically different. For these systems smaller bins such as those described above are emptied by the waste generator into a larger container with a volume **up to 40 m^3.** Once full the large container is removed from the waste collection point and replaced by an empty container. Fig. 34. shows typical collection vehicles for "change the bin" systems.

"Change the bin" system	
Advantages	**Disadvantages**
+ Suitable for high volumes of waste	- Bad ease of use for the user
+ Suitable for waste with high specific gravity	- High required space for pick up and drop off
+ High profitability	- High logistic expense
+ Offer of a variety of containers for various intended uses	
+ Possibility of flexible collection according to requirements	

Table 8: Advantages and disadvantages of the "Change the bin" system

Fig. 34. Example of container change vehicles

One-way bag system

The one-way bag system refers to a collection where the residual waste or the secondary resources are placed in plastic bags with the bags once full placed for collection in the front of the property. Service personnel must pick up the bags by hand and place into the collection vehicle. In some special cases one-way containers are used e.g. for pathogen hospital waste.

An advantage of the bag collection is the high collection capacity with say 1500 bags per day and loader. This is caused by the fact that the collection receptacle, i.e. the bag, is collected together with the waste and must not be brought back to its collection point as for bins, thereby saving time.

One-way container/bag system	
Advantage	**Disadvantage**
+ High collection capacity	- Low ease of use
+ No special vehicles required	- High material consumption
	- High expense at the sorting plant to open the bags
	- High physical strain of the personnel

Table 9: Advantages and disadvantages of the one-way container/bag system

Transfer stations

The different collection vehicles have differing "operational radii" (i.e. the average distance between the collection area and the disposal point that should not to be exceeded under economic conditions): a donkey and cart, for example, has an operational radii of around 1.5 kilometer, while a compaction truck such as shown in Fig. 35. has a radii of say 20 km. If the disposal site is further from the collection areas than the operational radii of collection vehicles, a transfer station should be located in between. At transfer stations smaller quantities are transferred to larger transport units for bulk haul to disposal points. Two examples are shown below.

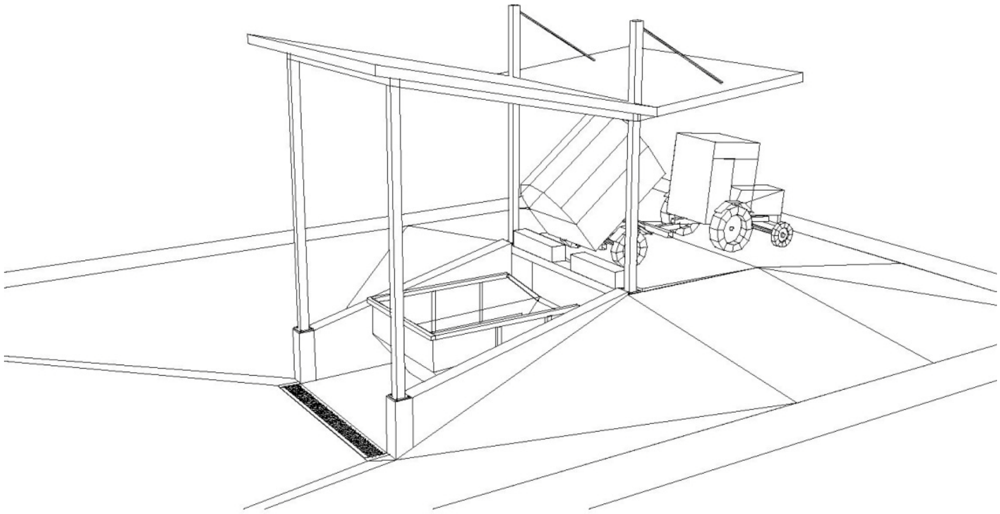


Fig. 35. Example of a simple transfer station

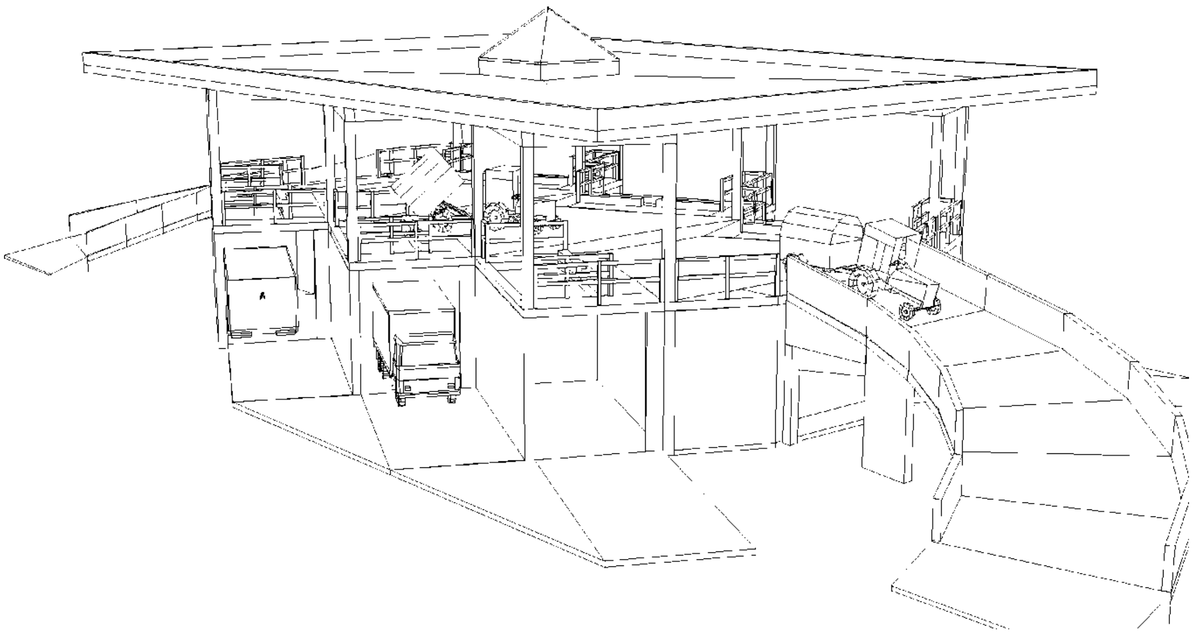


Fig. 36. Example of a more complex transfer station

3.4. Ways of collection

The organisation of waste collections has some significant differing attributes:

- Separate or combined collection of the different waste containers
- Frequency of emptying of the containers
- Initialisation of containers for emptying by waste collectors or users
- Collection vehicle staffing.

Separated or combined collection of the different waste containers

Different waste containers can be collected in separate tours or together in a single collection tour. This depends on the form and size of the containers and how many containers are to be collected. The planning of collection tours for residual waste and secondary resources is usually undertaken manually by experienced operators.

If the waste is separated prior to collection, fractions must be collected separately. Tour arrangement options include:

- separate collections of each fraction by different organisations (additive collections)
- separate collections of fractions through alternate collection timing (alternating collections) or
- simultaneous collection of fractions in a single vehicle (integrated).

Additive collection

If the collection of separated fractions of residual waste, biowaste, waste paper etc. is conducted totally independently of one another, this is called *additive* collection. For example, additive collection takes place when residual waste is picked up by the municipality and recyclables by a private contractor. As a consequence collection costs are considerably higher. In addition traffic impacts caused by vehicles are significantly higher than with alternating or integrated tour collection arrangements.

Additive collection	
Advantages	**Disadvantages**
+ Independence between residual waste collection and secondary resource collection	- High costs
+ Existing containers can be used	- High traffic burden
+ Existing vehicles can be used	
+ Possibility of collection of many different fractions	

Table 10: Advantages and disadvantages of additive collection

Alternating collection

For alternating collections, residual wastes and specific secondary resources are picked up according to a fixed timetable at specific intervals. Normally, for both fractions the same vehicle is used. This procedure requires some technical modifications to collection vehicles.

Alternating collection	
Advantages	**Disadvantages**
+ Low traffic burden	- Emptying intervals are depending on each other
+ Existing vehicles can be used	- Limited number of fractions

Table 11: Advantages and disadvantages of alternating collection

Integrated collection

Integrated collection involves pickup of different waste fractions at the same time and in a single tour with the same collection vehicle. Multi compartment collection vehicles are required. Experience has shown that providing more than two compartments per vehicle is prohibitively expensive.

Integrated collection	
Advantages	**Disadvantages**
+ Low traffic burden	- Specific multi-compartment collection vehicles are required
	- High investment costs
	- Limited on two fractions
	- Emptying intervals are depending on each other
	- Unfeasible if disposal sites of the two fractions are in certain distance to each other

Table 12: Advantages and disadvantages of integrated collection

Frequency of emptying of the containers

The frequency of emptying the waste and secondary resource containers depends on the proportion of organics present and climate conditions. In Northern and Central Europe containers can be collected weekly or every two weeks especially in the winter. In Southern Europe bins must be emptied more often, at least in summer. Depending on the proportion of biowaste the interval should be at least twice a week.

The above-mentioned characteristics for classifying different collection systems can theoretically be arranged any way. Experience has shown that, from technical and economical viewpoints, some combinations are better than others. These are marked in Fig. 37. by green arrows.

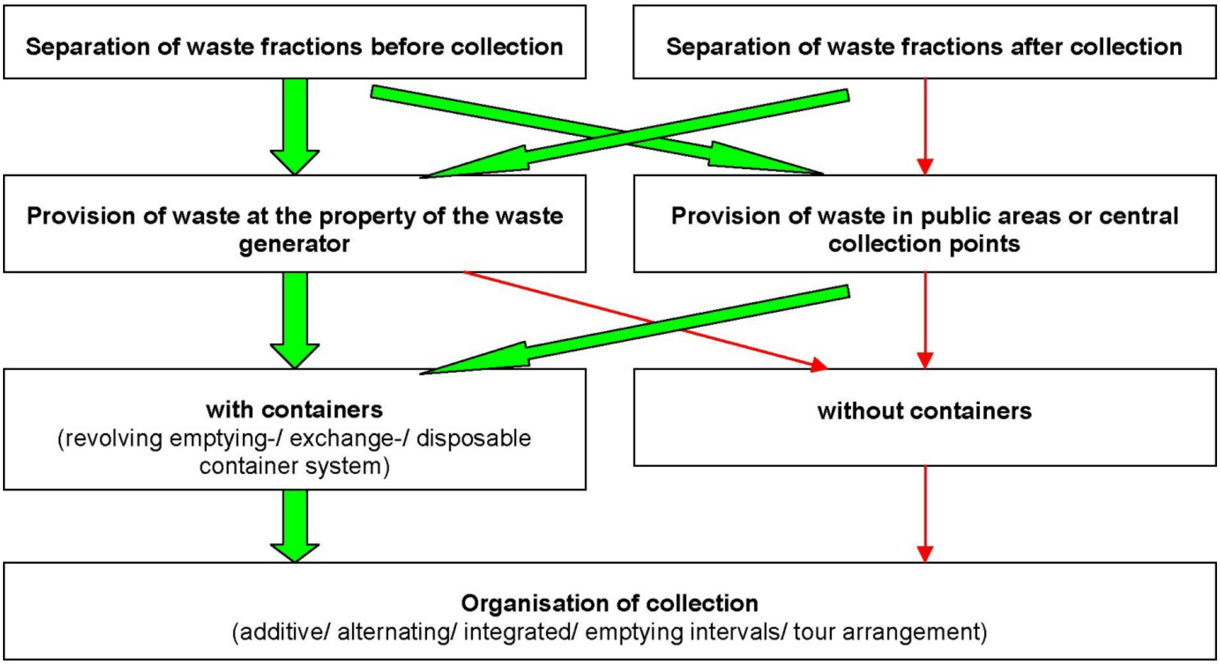


Fig. 37. Alternative methods of collection of waste

3.5. Automated Vacuum Collection

The automated vacuum waste collection system, also known as pneumatic refuse collection, or Automated Vacuum Collection System, transports waste at high speed through underground tunnels to a collection station where it is compacted and sealed in containers. When the container is full, it is transported away and emptied. The system helps facilitate separation and recycling of waste.

4. Chapter 4. WASTE TREATMENT: SORTING AND BIOLOGICAL TREATMENT

Waste treatment systems are chosen following consideration of the physical characteristics of the waste and the treatment objectives. As shown waste consists of many components with very different characteristics, e.g. organic waste from a domestic kitchen is totally different from plastic bags or glass bottles. Different treatment systems are therefore employed for single fractions than for mixed waste streams. The main waste treatment systems are shown in Table 13.

System	Technical variations	Waste fraction(s) to be treated	Products
Sorting	either by hand or mechanical	coarse fraction of mixed waste separately collected fractions such as paper, plastics, glass, demolition waste	Recyclable products for industrial use
Biological treatment	Composting Digestion	organic part of mixed waste separately collected organic waste	non-reactive material for later landfill usable compost, optional biogas
Incineration	Grate system Drum system pyrolysis, fluidised bed, cement industry, power plants	Mixed waste high calorific fraction after (mechanical) separation	Energy (electricity, heat, gas) Slag
Landfill	Construction categories following the harmfulness of the waste	Mixed waste, non-recyclable residues	none, except biogas and leachate requiring treatment

Table 13: Main systems for waste treatment

In practice, these coarse treatment options will often appear in combination with one another and will differ in the specific technical equipment. Meanwhile, for each treatment system a range of technical solutions is available. In general, the chosen system(s) must be carefully integrated in the waste management concept especially with regard to the capacity and the flexibility for upcoming developments.

A description of the waste treatment systems and their applicability is provided below.

4.1. Sorting

Sorting of waste at a MRF (Materials Recovery Facility) can be undertaken to extract resources from residual waste (this being preferred to simply *energy* recovery through incineration). In addition to manual sorting, and depending on the nature of the input material and output requirements different automatic steps can be employed to separate one or more fractions from the waste taking advantage of various physical characteristics. An overview is shown in Table 14.

Differentiating criterion	Treatment method / sorting machine
Particle size	> *Screening* with e.g. vibrating screens or trammel screens, common step applied prior to this one (and many others below) is > *Shredding* with hammer or cutting mills, breakers, pullers...
Suspense velocity	> Air sorter, vertical or zigzag classifier, ballistic sorter, hydraulic sorter
Being flat or able to roll	> Rolling freight separator, inclined sorting machine
Magnetic and electric characteristics	> Magnetic separator (for separating ferrous metals), > Eddy Current separator (for separating non-ferrous metals)
Optical / visual characteristics	IT-supported optical analyzers (used e.g. for sorting bottle glass in different colors)
Chemical or physical characteristics	> IT-assisted chemical analyzers (used e.g. for sorting a mixture of metal scrap

Table 14: Waste differentiation criteria and sorting methods

Manual sorting remains one of the most effective methods to extract secondary resources from MSW. Hand sorting can be optimized and supported by mechanical sorting machines. Manual sorting can broadly be classified as either positive or negative sorting.

Positive sorting means that resources are taken out of the waste stream on a selective basis. Negative sorting means that foreign material is selectively sorted out and the resource remains on the sorting belt. An example of positive manual sorting is given in Fig. 38. A typical scheme of a plant followed by a view is given below.

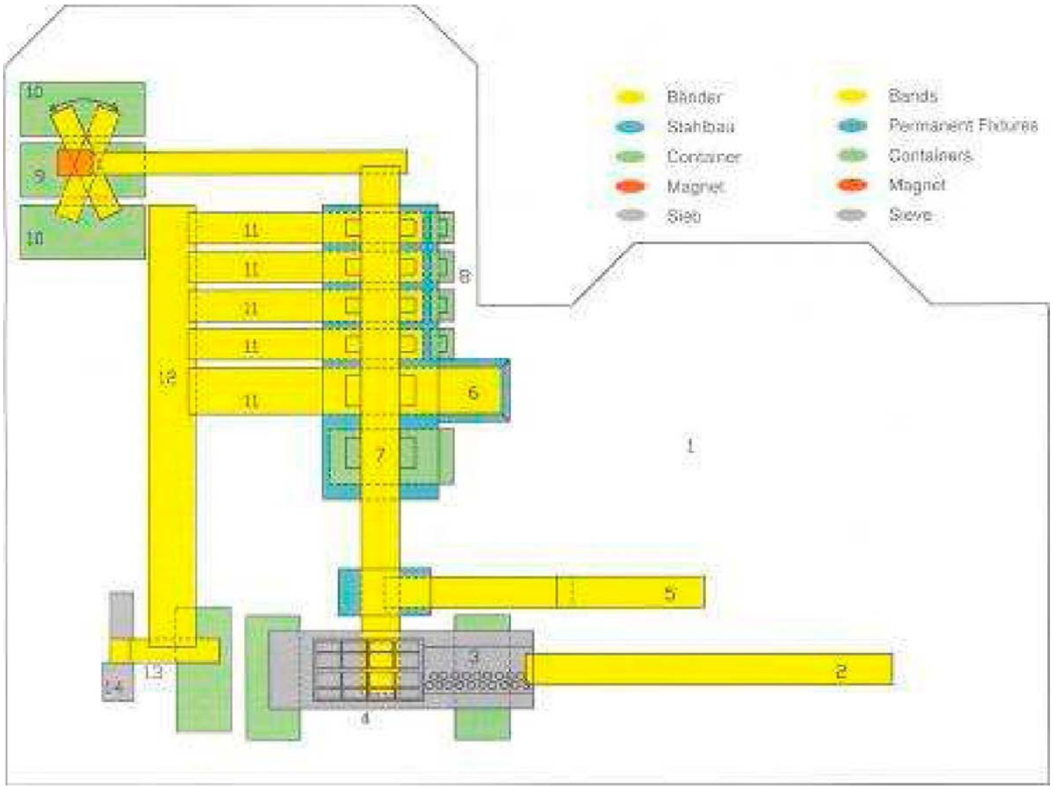


Fig. 38. Sorting plant for recyclables, bulky and commercial waste

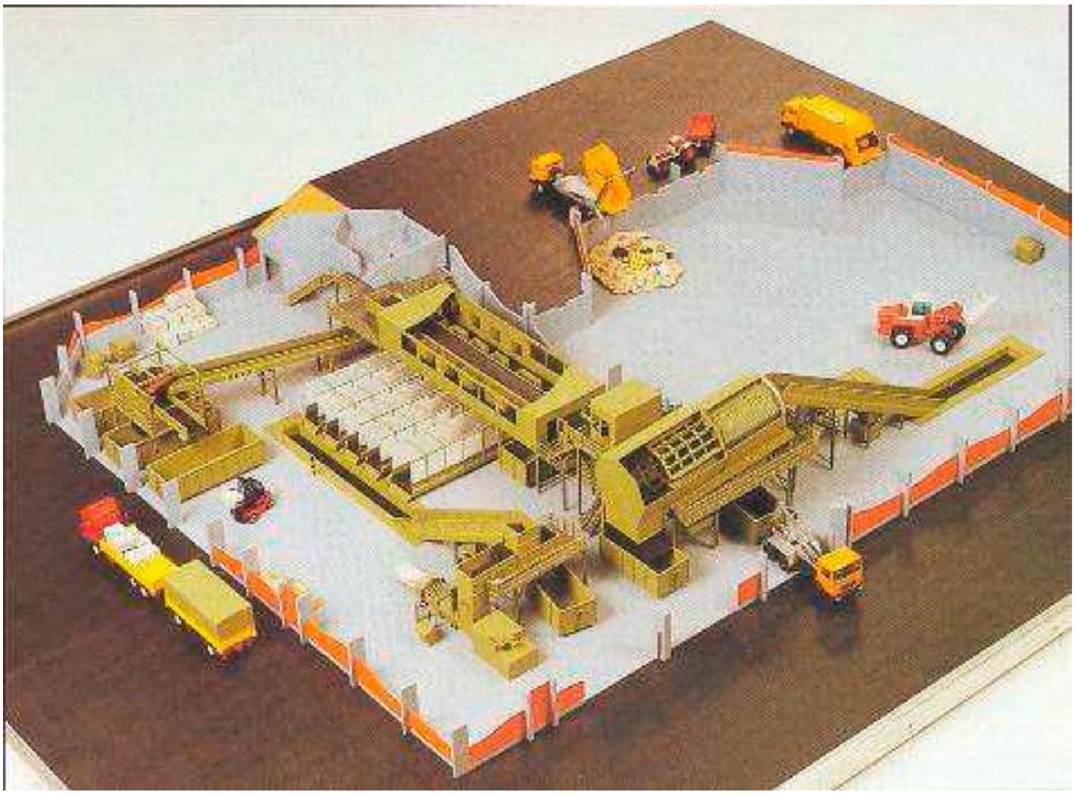


Fig. 39. Model of a sorting plant for recyclables, bulky and commercial waste as a front-end facility for a landfill

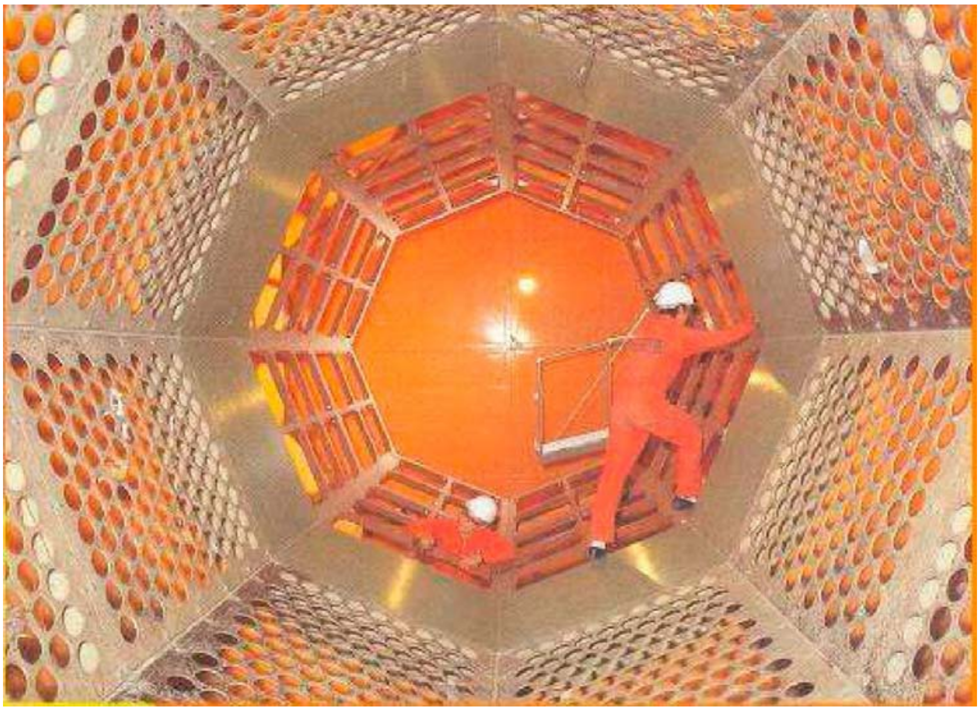


Fig. 40. View in trommel screen (out of plant shown on previous page)


Fig. 41. Sorting plant in Istanbul

4.2. Biological Treatment

4.2.1. Development

Organic waste (garden waste such as lawn clippings, plant trimmings, leaves and kitchen waste such as leftovers from fruit and vegetables) typically form 30 - 50 %, and therefore the largest component, of municipal household waste. Historically a high priority has been placed on separating out this organic fraction of the waste and to process it into compost, rich in humus and nutrients, for use in agriculture.

In the second half of the 20th century a number of MSW-compost facilities were built. They separated the organic parts mechanically from the mixed waste and converted it to compost. However as analytical assessment techniques developed, it was found that this compost contained high levels of with heavy metals caused by non-organic pollutants.

Compost from mixed household waste holds a five- to tenfold concentration of heavy metals compared to compost derived from pure organics. Mechanical improvements at the MSW-composting facilities could not improve the situation. Over the long term, using compost of mixed waste can be expected to result in accumulation of heavy metals in soil. This problem can only be solved in a sustainable way through separate collection of organic material, thus providing higher quality compost containing low amounts of heavy metals and visual impurities.

Therefore, there have been three main historical stages of development in the management of organic matter in waste as follows:

- *no biological treatment at all,* with waste going direct to landfill
- biological treatment of mixed *waste*
- biological treatment of separate collected organic matter

In addition to the pure "recycling approach", there is now another driving force which will spread the treatment of organic kitchen and garden waste beyond some Central European states (which always have been somewhat more developed in terms of environmental protection practices) to all over the continent: Current legislation of the European Community requires all member states (currently 27 states covering a population of 450 million; Europe in the geographical sense comes up to about 510 million) to reduce the biodegradable component of municipal waste significantly over the time: The amount of *Biodegradable Municipal Waste* [3] must be reduced (from a 1999 base):

- up to the year 2006, by 25 % (by weight)
- up to the year 2009, by 50 %
- up to the year 2016, by 65 %.

Biological treatment (i.e. composting and/or fermentation), in its potential to reduce biological activity in treated material, can be used to help meet the above targets in either of the following ways:

- *to produce matured, applicable compost* from separately collected organic materials

[3] comprising kitchen and garden waste, paper products, partly textiles

- *to produce a long-term inactive landfill material* from mixed waste by stabilising the organic component ("MBT" - Treatment)

4.2.2. 4.2.2. General systematic of biological treatment - Aerobic and anaerobic treatment processes

The purpose of biological waste treatment is to converts the pollutants to cell mass, water, and gases.

Biological treatment is an integral part of municipality or industry wastewater treatment having soluble organic components.

There are two main ways of biological waste treatment – aerobic and anaerobic treatment processes. Aerobic, as the title suggests, means in the presence of air (oxygen), while anaerobic means in the absence of air (oxygen). These two terms are related to the type of microbes that are involved in the degradation of organic substances. The aerobic treatment utilizes microorganisms (aerobes), which use free oxygen to assimilate organic impurities and convert them into carbon dioxide, water and biomass. The anaerobic treatment takes place in the absence of air (and free oxygen) by microorganisms (anaerobes) which do not require air (free oxygen) to assimilate organic impurities. The final products of anaerobic treatment are methane and carbon dioxide gas and biomass.

The pictures in Fig. 42. and 43. depict simplified principles of the two processes.

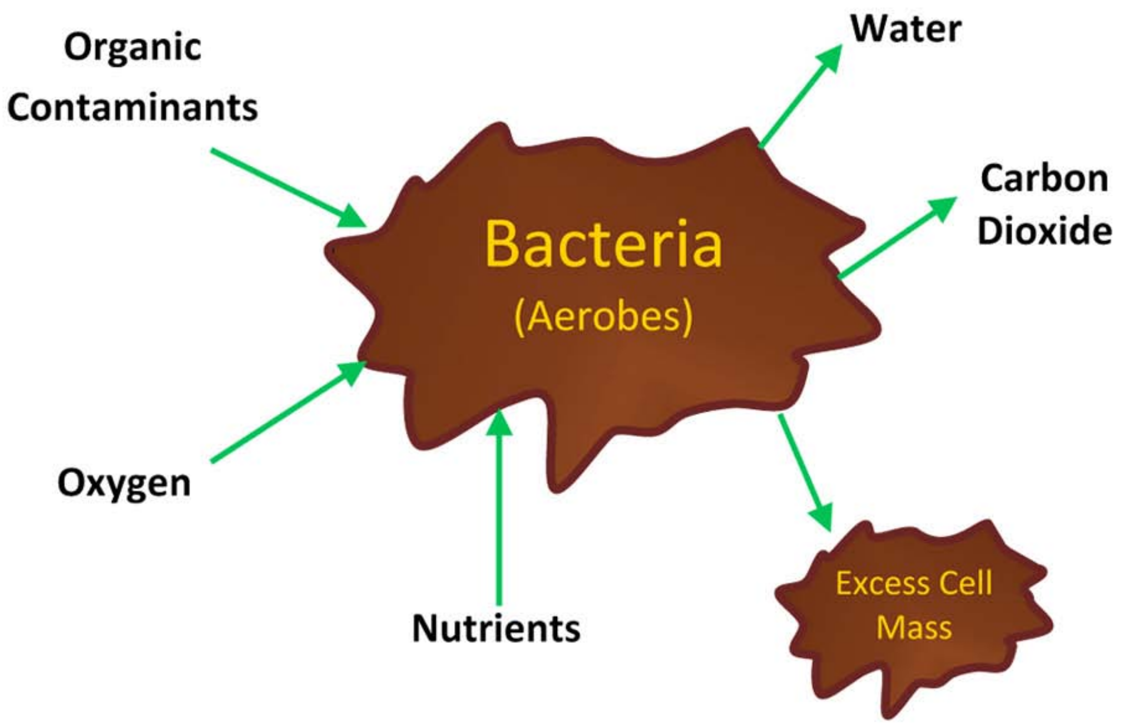


Figure 42. Aerobic Treatment Principle

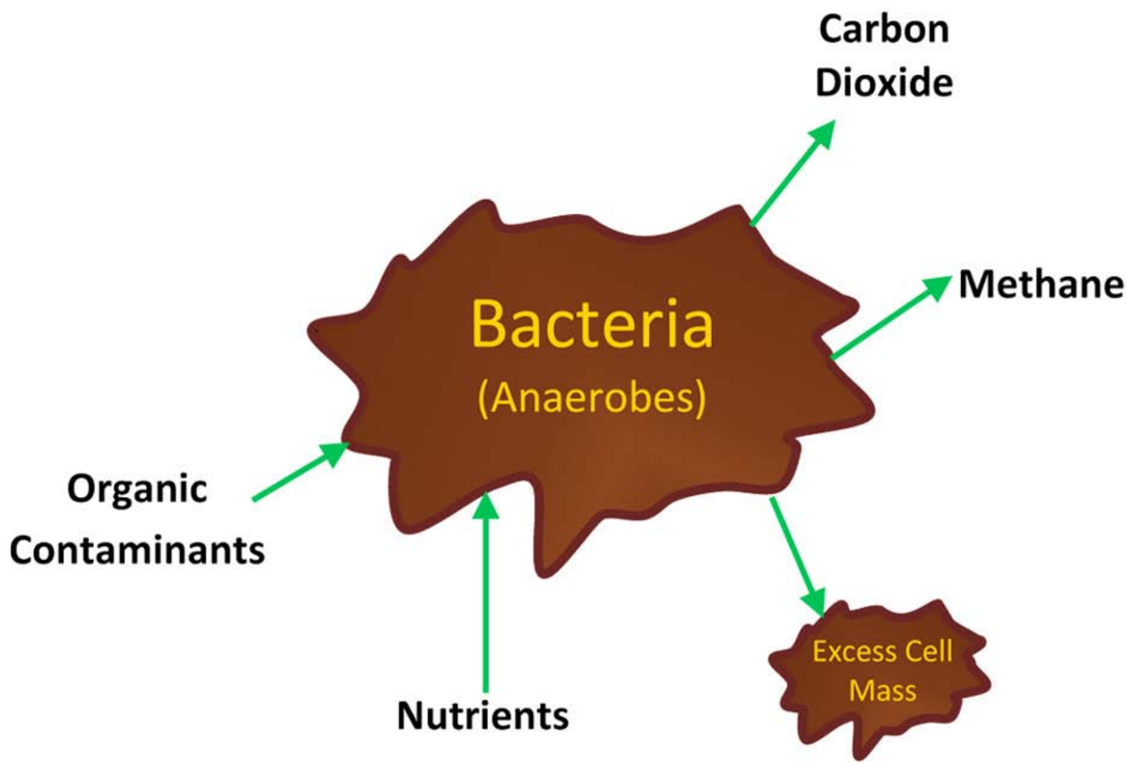


Figure 43. Anaerobic Treatment Principle

Source:Arun Mittal Biological Wastewater Treatment Water Today l August – 2011

MORE:
Table 15. summarizes the major differences in these two types of processes.

PARAMETER	AEROBIC TREATMENT	ANAEROBIC TREATMENT
Process Principle and End Products	▪ In presence of oxygen ▪ End products – CO_2,H_2O, excess biomass	▪ In absence of oxygen ▪ End products – CO_2, CH_4, excess biomass
Applications	Wastewater with low to medium organic impurities (COD < 1000 ppm) and for wastewater that are difficult to biodegrade e.g. municipal sewage, refinery wastewater	Wastewater with medium to high organic impurities (COD > 1000 ppm) and easily biodegradable wastewater e.g. food and beverage wastewater rich in starch/sugar/alcohol
Reaction Kinetic	Relatively fast	Relatively slow
Net Sludge Yield	Relatively high	Relatively low (generally one fifth to one tenth of aerobic treatment processes)
Post Treatment	Typically direct discharge or filtration/disinfection	Invariably followed by aerobic treatment
Foot-Print	Relatively large	Relatively small and compact
Capital Investment	Relatively high	Relatively low with pay back
Technologies	Activated Sludge e.g. Extended Aeration, Oxidation Ditch, MBR, Fixed Film Processes e.g. Trickling Filter/Biotower, BAF, MBBR or Hybrid Processes e.g. IFAS	Continuously stirred tank reactor/digester, Upflow Anaerobic sludge Blanket (UASB), Ultra High Rate Fluidized Bed reactors e.g. EGSBTM, ICTM etc.

Table 15: Major Differences in Aerobic and Anaerobic Treatment

Source: Arun Mittal, Biological Wastewater Treatment, 36 Water Today l August - 2011

The organic waste fraction can be treated either through *composting* or *anaerobic digestion* (usually abbreviated as AD, also the term *fermentation* is in use). Digestion is recommended more for wet material collected from inner city areas and industrial activities e.g. from the food industry. Through digestion, the production of biogas enables energy recovery from the material.

Composting is a cheaper treatment method, especially for smaller treatment units (in the range of 5.000 - 20.000 tons/year) and requires more structured material for a good aeration.

Parameter	Composting	Anaerobic digestion (AD)
Proliferation of micro organisms	F a s t (aerobic organisms)	S l o w (anaerobic methane bacteria)
Input material	stable structure, humidity < 65 %, = "solid"	Low structure Humidity > 65 % = "slurry"
Products	CO_2, H_2O, compost	CH_4, CO_2, AD residue, typically transformed to compost
Energy Production	H e a t (evaporated Water)	B i o g a s (70 % CH_4, 30 % CO_2) Heating value 7 kWh/m^3
Degradation time	7 - 10 weeks	1 - 3 weeks (plus 2 - 4 weeks maturation
Sensitivity to surroundings (temperature, pH)	low	high (especially methane organisms)
Energy (electrical) Input/Output/Net	-15 to - 40/0/-40 kWh/t	- 60/210/150 kWh/t
Leachate/waste water	-50 - 50 l/t	300 - 400 l/t from dewatering of AD residue
Area Requirements	0,5 - 1 m^2/t,a	0,2 - 0,7 m^2/t,a
Treatment costs	30 - 70 €/t	50 - 80 €/t
Unit investment	100 - 400 €/t	400 - 700 €/t

Table 16: Characteristics of composting and anaerobic digestion

For biological treatment of organic waste the most important task is the avoidance and elimination of odour emissions, since this is the major source of complaints from surrounding areas. For this reason, composting facilities of more than say 20.000 t/a should be enclosed, capturing and removing odour from exhaust air using a bio-filter.

Depending on location, smaller sites may also need to be enclosed and include odour treatment equipment.Open windrow composting. Open windrow composting is the simplest composting system and can be installed very easily when only smaller amounts of green waste are to be treated. The technical process comprises placement of organics in windrows, preferably on a concrete-paved surface, roughly over an area of 0.8 m^2 per ton a year (meaning that for 5.000 tons per year area of 4.000 m2 would be needed). Processing at a closed landfill is also possible. For quantities above 10.000 tons/year processed at a single site, it is economically feasible to purchase equipment such as a shredder, turning machine and a mobile drum screen to refine the compost. For smaller sites equipment should rotate and be shared over a number of sites.

Fig. 44.Green yard waste composting area

4.2.3. Indoor / In vessel composting systems

For treating larger quantities of biodegradable waste with a higher odour emission potential - which might be a problem at sites close to sensitive land use areas and dwellings - enclosed processing systems are recommended. The odorous air is captured and treated in a bio-filter. The most established systems are:

> the tunnel composting system, each holding about 200 m^3 material in a set of 10 to 40 aerated tunnels

> the indoor turning system, where a specialized machine moves through a 2- m thick layer of rotting material, gradually conveying the material over several weeks to the compost outlet.

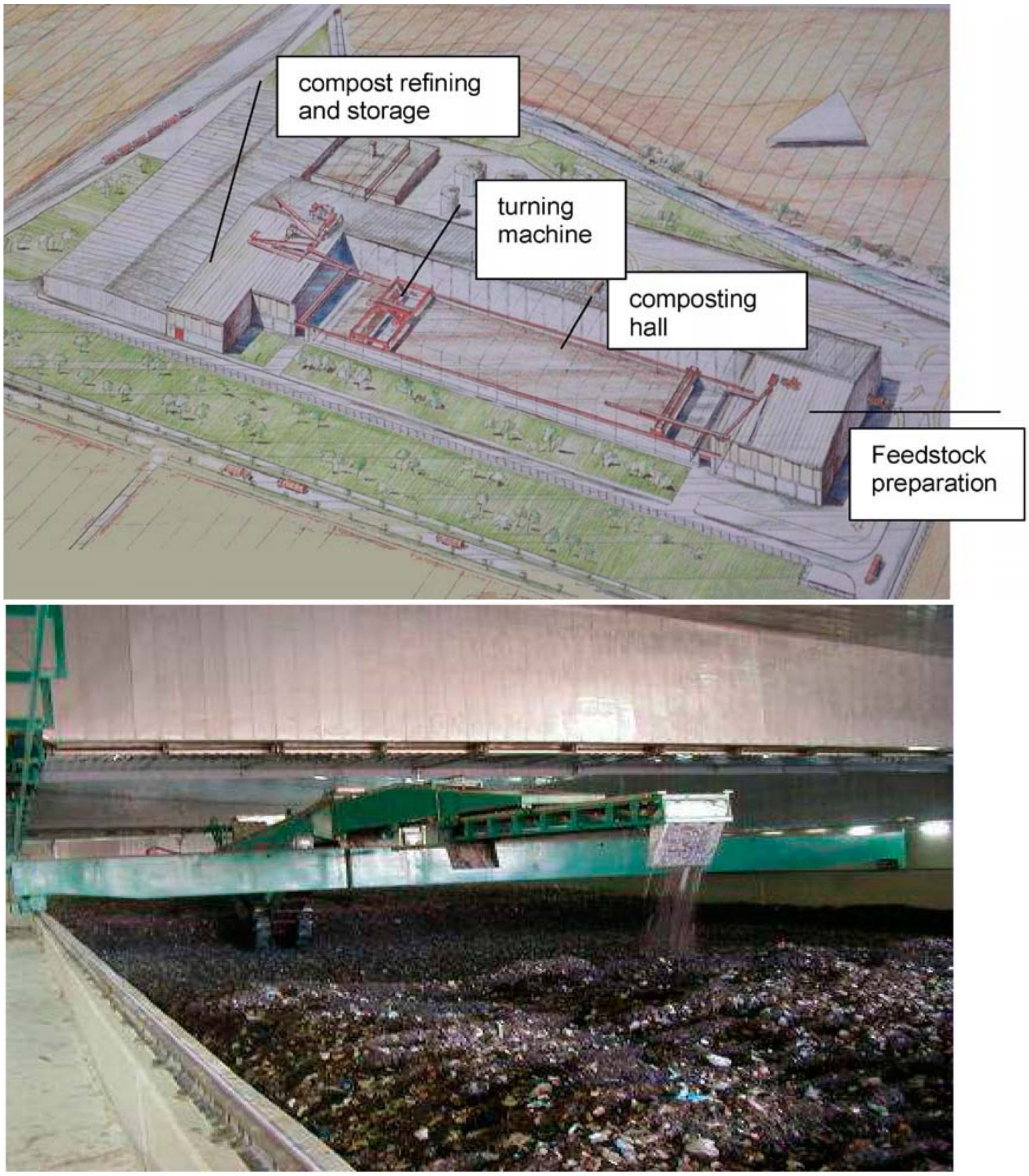


Fig. 45. Schematic of an indoor composting system

4.2.4. Digestion Systems - Sewage and Wastewater Treatment

Human activities generate a tremendous volume of sewage and wastewater that require treatment before discharge into waterways. Often this wastewater contains excessive amounts of nitrogen, phosphorus, and metal compounds, as well as organic pollutants that would overwhelm waterways with an unreasonable burden. Wastewater also contains chemical wastes that are not biodegradable, as well as pathogenic microorganisms that can cause infectious disease.

Sewage and wastewater treatment

Its treatment involves a procedure for water purification because the volume of organic matter and the variety and number of microorganisms are great.

MORE:

The first step, or primary treatment, of sewage and wastewater involves the removal in settling tanks of particulate matter such as plant waste. The solids that sediment are strained off, and the sludge is collected to be burned or buried in landfills. Alternatively, it can be treated in an anaerobic sludge-digesting tank, as follows.

During the secondary treatment of wastewater and sewage, the microbial population of liquid and sludge waste is reduced. In the anaerobic sludge digester, microorganisms break down the organic matter of proteins, lipids, and cellulose into smaller substances for metabolism by other organisms. Results of these breakdowns include organic acids, alcohols, and simple compounds. Methane gas is produced in the sludge tank, and it can be burned as a fuel to operate the waste treatment facility. The remaining sludge is incinerated or buried in a landfill, and its fluid is recycled and purified.

http://www.cliffsnotes.com/study_guide/Sewage-and-Wastewater-Treatment

Some of the methods used for sewage and wastewater treatment:

Trickling Filters

There are several different types of trickling filters but all are based on the same basic principles. There must be a period when drainage is good so air can percolate into the matrix. Organisms attach themselves to the solid medium and get their nutrients from the liquid and oxygen from the air.

Fig.46.Trickling filter, sewage-treatment plant, Henderson, USA

www.industrial-landscape.com

http://www.youtube.com/watch?v=g7XaUbDqZ6k

Activated Sludge

Activated sludge units are usually tanks constructed on site or fabricated units. In both constructions, the feed enters a zone that is aerated so air bubbles and liquid have a good contact. The aeration could be evenly distributed throughout the tank, tapered or stepped, depending on the process demand.

Fig.47.Activated sludge aeration basins

www.slcclassic.com

http://www.youtube.com/watch?v=arPqPoFOQUM

Aerated Lagoons

Wastewater lagoons have been used as a process for wastewater treatment for centuries. By 1950, the use of artificial ponds had become as an economical wastewater treatment method for small municipalities and industries. From 1980, approximately 7000 waste stabilization lagoons have been in use in the USA. Today, one third of all secondary wastewater treatment facilities include a pond system of one type or another. Ponds can be used for larger cities for wastewater treatment as well. Some of the largest pond systems in USA are in Northern California, serving such cities as Sunnyvale (pop. 105,000), Modesto (pop. 150,000), Napa (pop. 175,000), and Stockton (pop. 275,000).

Fig.48.Aerated lagoons http://ww

w.lagoonsonline.com/

http://www.youtube.com/watch?v=YctXi9jDK8U

The chemical and biological waste in sewage and wastewater must be broken down before it is deposited to the soil and environment. This breakdown can be controlled by managing the microbial population in waters and encouraging microorganisms to digest the organic matter. The water must then be purified before it is considered fit to drink. Water taken from ground sources must also be treated before consumption.

Water purification

Water purification is the process of removing chemicals, biological contaminants, suspended solids and gases from contaminated water. The goal is to produce water fit for a specific purpose. Most water is purified for human consumption (drinking water), but water purification may also be designed for a variety of other purposes - medical, pharmacological, chemical and industrial applications. In general the methods used include physical processes such as filtration, sedimentation, and distillation, biological processes such as slow sand filters or biologically active carbon, chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light.

MORE:

To purify water for drinking, a number of processes are conducted to reduce the microbial population and maintain that population at a safe level. First, the solid matter is allowed to settle out in a sedimentation tank**.** Different materials such as alum are used to drag microorganisms to the bottom of the tank.

Then the filtration process is begun. Water is filtered through either a slow sand filter or a rapid sand filter**.** These processes remove 99 percent of the microorganisms. The slow sand filter is composed of finer grains of sand, and the filtration process takes longer than in the rapid sand filter, where larger grains are used.

Many communities then purify the water by chlorination. When added to water, chlorine reduces microbial count and ensures that the water remains safe for drinking purposes. Chlorine gas or hypochlorite (NaOCl) is used for chlorination. In Europe widely used also ozone disinfection. Ozone is an unstable molecule which rapidly gives up one atom of oxygen providing a powerful oxidizing agent which is toxic to most waterborne organisms.

Digestion systems producing about 100 m^3 biogas per ton are used to treat only a relatively small proportion (10 -15 %) of *solid* organic waste, since they are more expensive to install than composting systems. For the treatment of *liquid* manure in agriculture, digestion systems are well established, usually employing low-tech systems, with lower biogas production efficiency. With the increased emphasis on energy recovery from of organic matter - which is not the case with composting - digestion is expected to gain more and more importance in the coming years.

Digestion takes place in a completely closed system, with organic material fermented in a suspended or solid consistency. The required population of methanogenic microorganisms is re-fed to the fresh material or maintained in the suspended phase. The retention time in digesters is typically three weeks, by which time all the available organic matter has converted to biogas, which consists of 60-65 % of methane. The biogas is stored and used as a fuel for an adapted diesel-engine, producing electricity by a generator.

The digestion residue is either directly applied to agricultural land or, owing to its highly odorous nature, is converted in an aerated maturation phase to compost prior to use.

Unlike composting processes, where moisture present in organic waste - in range of 60 % or above - is evaporated by the heat generated, in digestion the water remains in the material. If this water cannot be used in agriculture as a fertilizer, it must be treated before being released in the public wastewater system.

Fig. 49. Digestion facility for biowaste with biogas-engine

4.2.5. Mechanical-Biological Treatment

What is Mechanical Biological Treatment, or MBT? For the past 10 years or so this technical term has been used to represent a range of technologies and combinations thereof. MBT is thus probably less clearly defined than incineration, which has maintained its basic process for some decades. In contrast to conventional incineration, MBT involves several mechanical (pre-)

processing steps (at least grinding and/or screening) as well as the degradation of organic matter through biological activity. Sometimes complementing these activities is the separation of plastics and other "biologically inert" fractions, an effect which in advanced systems results in further resource recovery, e.g. production of secondary fuels.

The term MBT adopted here relates to systems for the treatment of municipal solid waste: a treatment facility for any type of separately collected organic wastes is not an MBT facility. Mechanical treatment (MT) plants are included under MBT if the waste materials are subsequently processed by a material-flow-specific treatment method (e.g. thermal treatment of fractions with a high calorific value, here generally referred to as refuse-derived fuel/RDF).

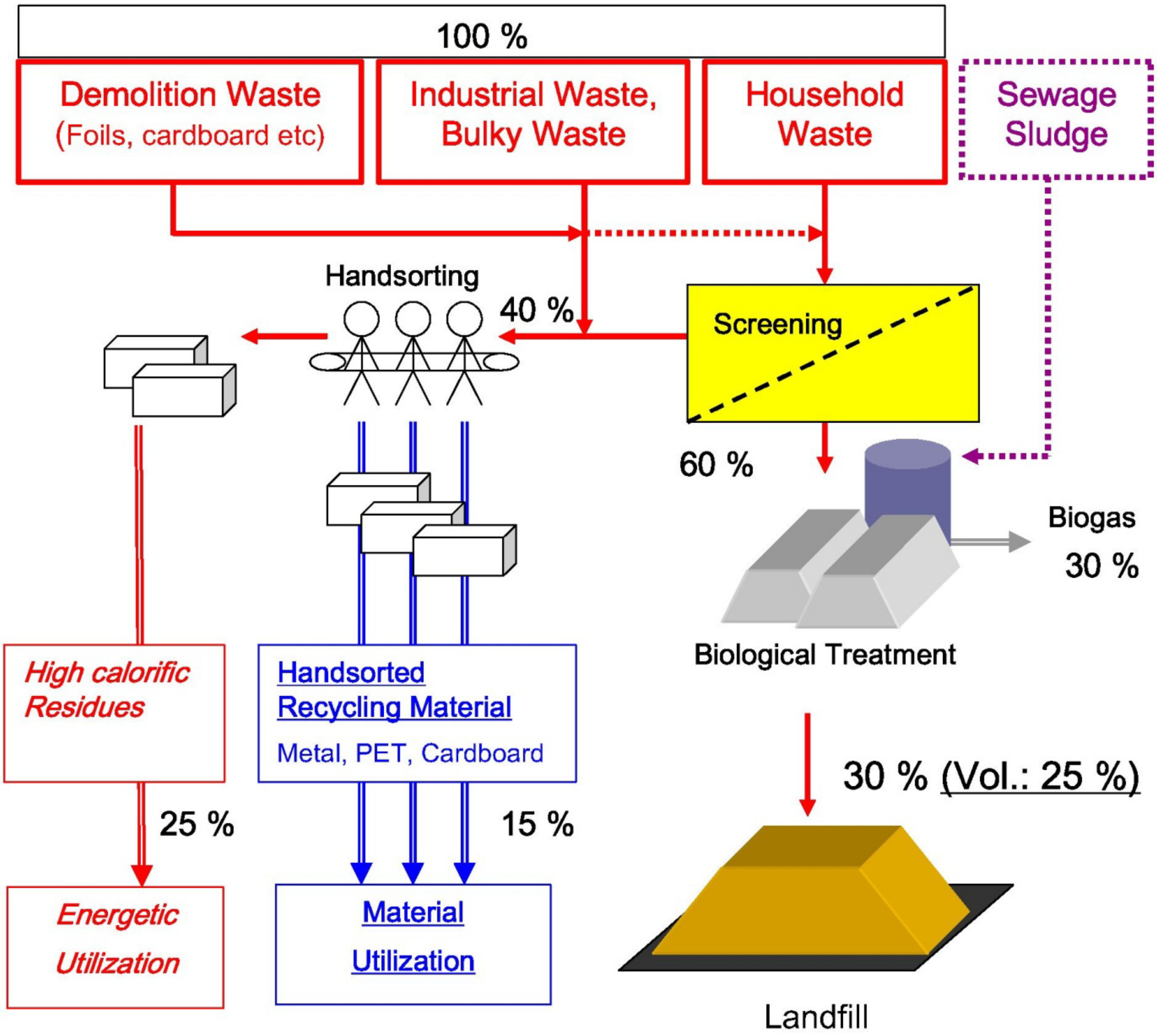


Fig. 50. Typical scheme of a mechanical-biological treatment of MSW

Within the biological treatment phase the degradation of organic matter, which normally takes place in a landfill over 50 years or more, takes place in highly effective MBT facilities over some months, thereby reducing the potential to produce landfill gas by more than 95 %. The MBT by-product is comparable in its inert character to incineration slags. In fact, in higher developed waste management concepts MT and MBT processes are generally followed by a thermal treatment step (predominantly fluidized bed rather than grate incineration). So, a future classification of waste treatment may read "Conventional Waste-to-Energy plants vs. Combined Treatment systems" in place of the currently used "Thermal vs. Mechanical-biological waste treatment".

The installation of a MBT is not intended to act as a substitute for biowaste collection and recovery, which is perhaps introduced later: Most of the biological systems for MBT allow for separate treatment of biowaste (in one line) and the screened fine material of MSW (in the other line). Thus, the biological capacity can be used for the different input materials ("double-duty sites").

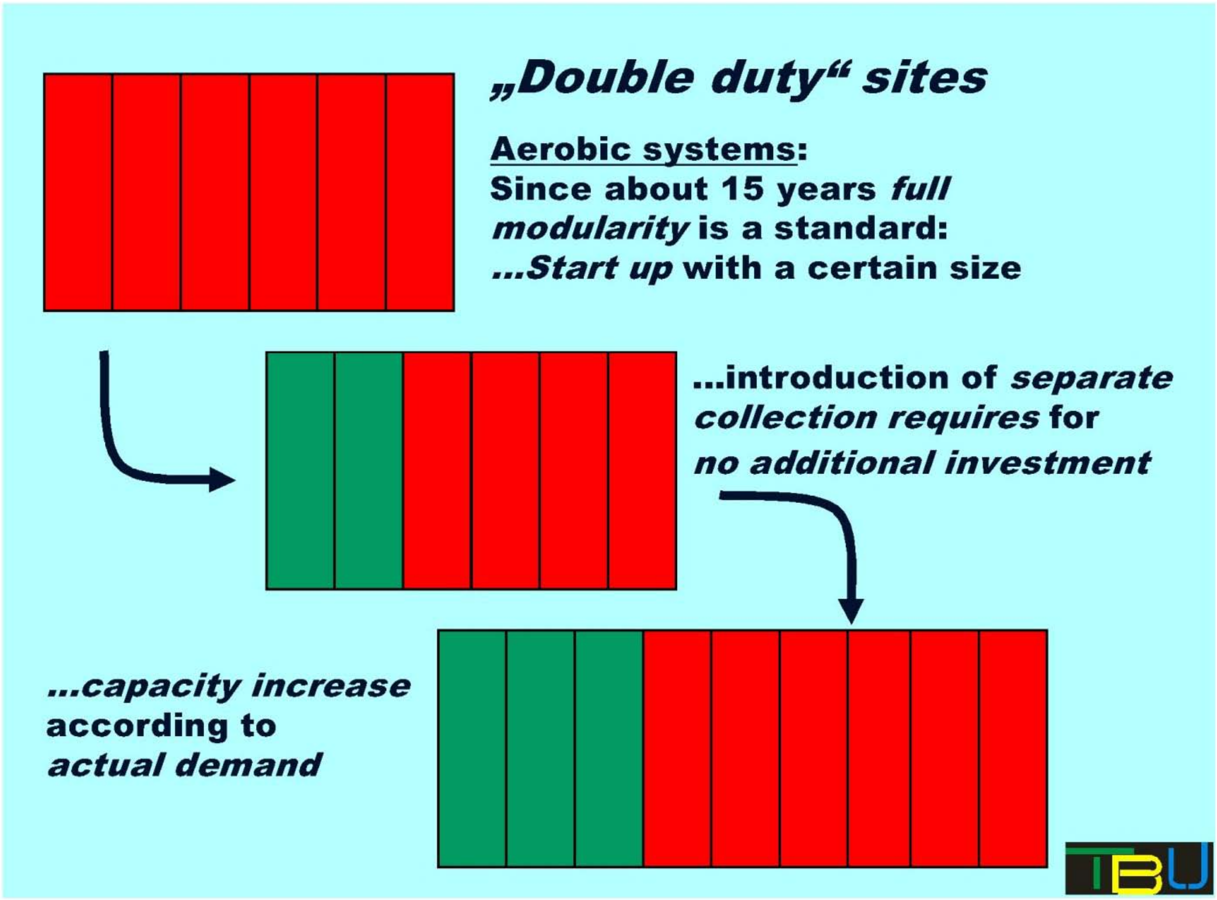


Fig. 51. Example for flexibility of MBT

Fig. 52. View Hanover MBT plant Hanover, Germany's largest MBT facility (200.000 tpy).

5. Chapter 5. WASTE TREATMENT: THERMAL TREATMENT AND LANDFILL

5.1. Thermal Treatment

The combustion of waste fractions was first applied in Europe in the 1870's (Oldham, England). Since then technical standards have developed and today the technology can be called thermal treatment.

Thermal treatment processes are used to reduce the volume and the weight of waste requiring disposal as well as to recover energy. The original volume of the combustible fraction of MSW can be reduced by 85 to 95%. This is of special importance if waste management solutions for densely populated areas are required, because waste generation is increasing and the available landfill space is limited. In addition the recovery of energy in the form of heat is another attractive feature of the thermal treatment processes. Although combustion technology has developed in recent years, air pollution remains a major concern in implementation.

Thermal treatment of waste must fulfill the following requirements:

- render inert the contained organics by thermal oxidation,
- destroy organic pollutants and to concentrate inorganic pollutants,
- reduce mass and volume of waste streams, and
- recover energy to preserve energy resources.

Fig. 53. MBT Istanbul: Mechanical pre-treatment (left), turning system in aerobic biological stabilization system (right)

Recently reported difficulties in Germany refer mainly to anaerobic systems - one internationally well registered technology supplier has left the market in 2001, and certain faults in the start-up phase of new plants have been widely reported. Similar developments have been observed with the "thermal processing option" with certain fancy concepts in the last two decades, and not every burst pipe in a WtoE plant's heat exchanger has finally turned out as a show stopper...

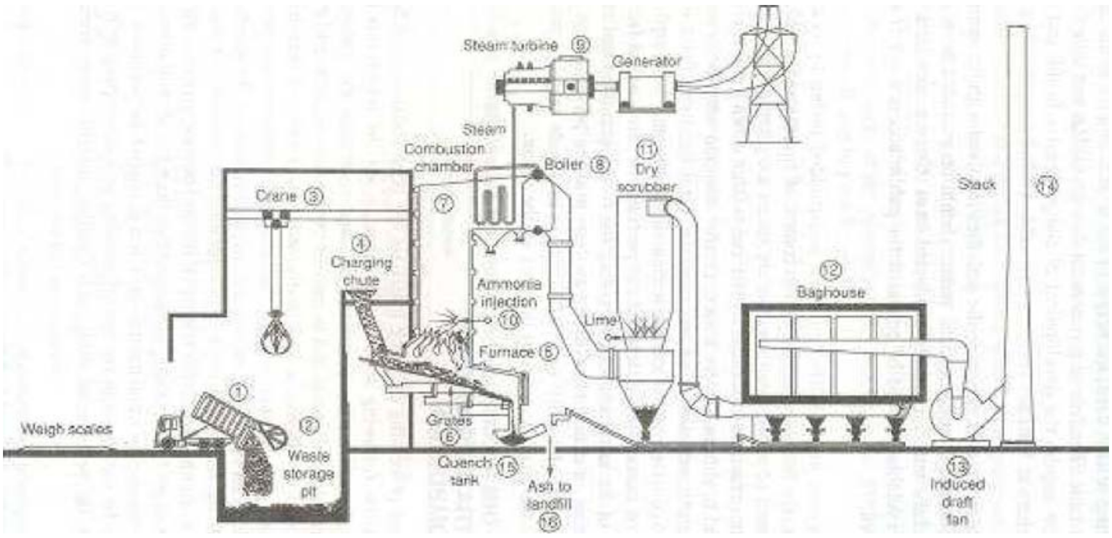


Fig. 54. MSW incineration plant [Integrated solid waste management, Tchobanoglous, p.292]

5.1.1. Incineration

Incineration of solid waste can be defined as the conversion of wastes by chemical oxidation with stoichiometric or excess amounts of air into gaseous, liquid and solid conversion products with the corresponding release of heat.

The layout of a classical incineration plant is shown in Fig. 54. At the infeed point the collection truck (1) unloads the solid waste into the storage pit (2). The capacity of the storage pit is usually equivalent to the volume of two day's waste. The crane (3) loads the waste into the feed chute (4), from where the waste is conveyed to the furnace (5). Afterwards the waste falls onto the grates (6) where it is combusted. As most organic wastes are thermally unstable, various gases are driven off at this point. These gases and small particles rise into the combustion chamber (7) and burn at temperatures in excess of 900°C. Heat is recovered from the hot gases by water pipes that are connected to a boiler (8) that produces steam which is converted to electricity by a turbine-generator (9). Air pollution control equipment should include NO_X control (10), a dry scrubber for SO_2, acid gas control (11), and a bag house filter for particulate removal (12). Also used are cyclones, and electrostatic filters. To ensure adequate air flow an induced-draft fan (13) must also be provided. The end products of incineration are hot gases and ash. The cleaned gases are discharged to the stack (14). Ashes and inert materials from the grates fall into a residue hopper (15) located below the grates where they are quenched with water. Ash from the dry scrubber and the baghouse is mixed with furnace ash and conveyed to ash treatment facilities (16).

<u>Incineration products</u>

The principle elements of solid wastes are carbon, hydrogen, oxygen, nitrogen and sulphur. As mentioned above the main products of incineration are hot gases and ash. If the combustion is optimal, the *gaseous* products derived from incineration of municipal solid waste include carbon dioxide (CO_2), water (H_2O, flue gas), nitrogen (N_2), and small amounts of sulphur dioxide (SO_2).

<u>Types of input</u>

Incineration plants can be designed to burn different types of solid wastes. These include unseparated mixed municipal solid wastes and processed MSW known as refuse-derived fuel (RDF).

When processing mixed MSW the waste is not pre-treated. Because of its inhomogeneous character the energy content of the municipal solid waste can be highly variable, depending on climate, season and the source of the waste. Another criterion is the behavioural pattern of residents in separating waste at source, assuming that the municipality provides a separate collection of wastes.

MSW can also be processed to produce RDF for energy recovery at incineration plants. RDF is produced from the organic fraction of MSW with a defined energy content, moisture level and ash content. The RDF can be produced in shredded or fluff form, or as densified pellets or cubes. The densified RDF (d-RDF) is more expensive to produce but it has transport and storage advantages.

Due to the higher energy content of the RDF, the dedicated incineration plant for RDF can be smaller than a comparably rated plant for mixed waste. More space is however needed if the pre-treatment plant to produce the RDF is located adjacent to the incineration plant. Another advantage in operating a RDF incineration plant is the fact that it can be controlled more effectively due to the more homogeneous character of the RDF compared to mixed MSW. This includes better combustion control and better performance of air pollution control devices. The pre-treatment of MSW also enables the removal of other fractions such as metals, plastics and other materials that may contribute to harmful air emissions.

Energy recovery

Energy can be recovered at incineration plants by different methods:

- the use of a water-wall combustion chamber, or
- the use of waste heat boilers, or
- a combination of both.

Regardless of which method is used either hot water or steam can be generated. Hot water can be used for low-temperature industrial or space heating applications. Steam can be used for both heating and generating electricity.

Volume reduction

Volume reduction is one of the most important advantages of incineration compared to mechanical-biological treatment. Urban areas in particular have the need to reduce waste volumes to solve the problem of the increasing waste generation on the one hand and limited landfill space on the other hand.

The amount of residue from incineration depends on the characteristics of the input waste. An example of residue from the combustion of mixed MSW is shown in Table 17.

Component	0 percentage of residue by weight
Partially burned or unburned organic matter	5 %
Tin cans	18 %
Other iron and steel	10 %
Other metals	2 %
Glass	35 %
Ceramics, stones, bricks	5 %
Ash	25 %

Table 17: Composition of residue from the combustion of commingled MSW

Issues in the implementation of incineration facilities

The design and implementation of incineration facilities for MSW is influenced by the following key factors:

- *Siting:* to minimize the impact of the operation of combustion facilities and to minimize the risks to environment and health they should be sited in more remote locations where adequate buffer zones surrounding the facility can be maintained.

- *Air emissions:* The products of incineration plants are many different gaseous and particulate emissions, many of which are thought to have serious health impacts. The proper design of control systems for these emissions is a critical part of the design of incineration systems. The costs and complexity of the environmental control system are similar or can even be higher than the combined costs of all of the remaining components of the incineration facility.

- *Disposal of residues:* The main solid residuals are bottom ash, fly ash and scrubber product. Typically the ash is disposed of by landfilling with the risk that it may leach contaminants into the ground water.
- *Liquid emissions:* The sources of liquid emissions can be
    - wastewater from the ash removal facilities,
    - effluent from wet scrubbers,
    - wastewater from pump seals, cleaning, flushing and general housekeeping activities,
    - wastewater from treatment systems used to produce high- quality boiler water, and
    - cooling tower blowdown.

  The proper handling of these liquid emissions is an important component of the implementation of incineration plants.

- *Economics:* The economics must be evaluated carefully to choose between competing systems. The best method of comparing alternative systems is the use of life-cycle-costing.

5.1.2. Other thermal treatment systems

Fluidised-bed furnace

A fluidized-bed furnace is an alternative to conventional incineration. It consists of a vertical cylinder with a sand bed, a supporting grid plate and air injection nozzles known as tuyeres. When air is forced up through the tuyeres the bed fluidizes and expands to up to twice its volume. The fluidized bed causes turbulence and transfers heat to the fuel. The solid fuels are injected into the reactor. Fluidized-bed furnace systems can be operated with many fuels including *MSW, sludge, coal* and numerous *chemical wastes.*

Pyrolysis systems

Pyrolysis is a thermal treatment process carried out in the complete absence of oxygen where an external heat source is used to drive the endothermic reaction. Because of their thermal instability the organic fraction is broken up, or 'cracked', into gaseous, liquid and solid constituents.

The main pyrolysis products are:

- a gas stream of mainly H_2, CH_4, CO, CO_2
- a liquid fraction consisting of a tar or oil stream containing acetic acid (CH3COOH), acetone (C3H6O), methanol CH3OH) and complex oxygenated hydrocarbons.
- char of almost pure carbon plus any inert material from the solid waste.

Gasification systems

Gasification is a process of combustion in which a fuel is burned with less air than needed for complete oxidation (i.e. less than stoichiometric air supply). The product is a combustible fuel gas rich in carbon monoxide (CO), hydrogen (H_2) and hydrocarbons especially methane (CH4). This combustible gas can be used as fuel in a gas turbine.

5.1.3. Environmental control systems

Over the many decades of its development, incineration has been observed to cause a range of environmental impacts from gaseous and particulate emissions, solid residues and liquid effluents. In the late 1970's it was discovered that, in particular, the flue gas from incineration contained high levels of noxious substances. This had the twin effects of:

a) an increase in recycling activities to reduce the amount of waste to be incinerated,

b) the introduction of strict EU-regulations for emission reduction and control for waste incineration plants.

The design of control systems for these emissions is the single most important issue in the planning and building an incineration plant. Because of their complexity the environmental control system can be more expensive than the combined cost of all of the remaining components of the incineration plant.

5.1.4. Environmental Consideration and Benefits

Toxin removal

As we mentioned, the products of incineration plants are many different gaseous and particulate emissions, many of which are thought to have serious health impacts. Since the early 1990s, research has studied the mechanisms by which dioxins and furans are formed during the incineration of materials containing chlorine. These chemicals are destroyed at normal incineration temperatures of 900°C. Recent technological advances have made it possible to reduce flue-gas dioxin emissions from incineration plant to less than half a part in a thousand billion.

MORE:

A remaining issue is the somewhat higher levels found in fly ash filtered from the exhaust gases. Fly ash also tends to contain most of the lead, cadmium and mercury present in the original waste. Currently, fly ash is buried at designated landfill sites appropriate for hazardous waste. A more environmentally friendly approach is to treat the fly ash, destroying dioxins and recovering heavy metals. The treated ash is then sent to a landfill site. Another important area for research is the treatment of exhaust gases. Many of the basic treatments such as filtration and scrubbing to remove acid gases are mature technologies. One important area of research for the immediate future will be instrumentation that can accurately measure exhaust emissions at the new levels set by European Union legislation.

Removing acidic gases

As well as removing particles at high temperatures, acidic gases such as sulfur dioxide and hydrogen chloride must also be removed.

This has particular benefit for gasification processes. For some processes, there is an efficiency advantage in cleaning hot gas and then burning it hot in a boiler or gas turbine. Correct selection of the bed material in a fluidised bed gasifier can reduce the acid gases. Work is also under way by VTT in Finland on hot gas cleaning and catalytic conversion techniques.

www.capenhurst.com
VTT, www.vtt.fi
Accentus plc, www.accentus.co.uk/html/indexenv_mset1

5.2. Landfill - Landfill of Waste – EU

Throughout the world landfills have historically been the most economical method for the disposal of solid wastes. Even with implementation of waste reduction, recycling and transformation technologies, disposal of residual solid waste in landfills still remains an important component of an integrated solid waste management strategy. The Directive 99/31/EC on the landfill of waste sets out requirements for wastes that are landfilled and for the design and operation of landfill sites. It defines landfill classes as follows:

- Landfills for hazardous waste
- Landfills for non-hazardous waste
- Landfills for inert waste

The following wastes are not accepted in a landfill:

- Liquid waste
- Explosive, corrosive, oxidising and flammable waste
- Hospital and clinical waste which are infectious

- Whole used tires

The directive indicates that only waste that has been subject to pre-treatment may be brought to a landfill. At a hazardous landfill only waste can be disposed that fulfils the criteria in Annex II of the directive. Landfills for non-hazardous waste may only be used for disposal of:

- Pre-treated municipal waste
- Non-hazardous waste which fulfill the criteria of this landfill class
- Stable non-reactive hazardous waste with leaching behaviour equivalent to those of non-hazardous waste

The annexes I to III of the directive deal with:

I. General requirements for all classes of landfills
II. Waste acceptance criteria and procedures
III. Control and monitoring procedures in operation and after-care phases

Legislation

Summary of EU Waste Legislation on Landfill:

- Directive 99/31/EC on landfill of waste
- Ancillary legislation relating to landfill of waste:

  - Commission Decision 2000/738/EC concerning a questionnaire for Member States reports on the implementation of Directive 1999/31/EC on the landfill of waste

- Proposal for a Decision on acceptance criteria, COM(2002) 512
- COUNCIL DECISION of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC (2003/33/EC)

5.2.1. Potential impacts from landfills

During the operation period of landfills and following closing, the associated air and water emissions represent a potential danger to humans, animals and plants, soil, water and air, climate and landscape.

The impacts arise from the release of pollutants in the leachate, the landfill-gas and during fires, as well as the risk of explosions.

5.2.1.1. Leachate

As water percolates through waste the nature of the waste and storage conditions produce contaminated *leachate* as a result of elution, stripping and chemical reactions. The leachate normally contains high amounts of organic matter, salt, nitrogen and other diluted chemicals.

Leachate represents a possible contamination risk for surface water, groundwater and subsoil. Compared to emissions of landfill gas, leachate is emitted over much longer time frames (decades).

The nature and quantity of the leachate are mainly dependent on:

- climatic conditions (water balance),
- type and composition of the waste,
- type of the landfilling technology (compaction),
- capability of the sealing-system, and
- age of the landfill.

While the landfill is operating, the quantity of leachate is equivalent to up to one third of the precipitation at the site.

Technical options for *leachate treatment* range from co-treatment in a conventional waste water (sewage) treatment plant to sophisticated (thus comparatively costly) technologies resulting in drinking water quality, such as reverse osmosis. A proven both low-cost and - if managed properly - effective concept applicable throughout most European weather zones is to recycle the leachate into the landfill body (example shown in Fig. 55.) where the intake of moisture, nutrients and microorganisms accelerate decomposition (resulting in higher gas yields and shorter periods of landfill activity).

Recirculation of leachate in landfills can be practiced under certain conditions to increase the degradation of organics thereby producing landfill gas. This requires a gas collection system and a surface cover to be installed. The example in Fig. 55. is not an appropriate form of leachate treatment and recirculation (except perhaps if the only other management option available was to discharge it to ground or surface water).

Fig. 55. Example of recirculation of leachate in Gjilan / Kosovo (Serbia, presently **administered by UN):** Acceptable practice only if the alternative would be to release the leachate into ground or surface water. More appropriate (due e.g. to aesthetic and health aspects): would be to recirculate it under a covered landfill area with a proper gas collection system operated in parallel.

5.2.1.2. Dust

Dust emissions can occur while unloading waste from trucks and handling waste at the surface of the landfill. Wind-borne dust emission can also take place when dusty materials are not covered immediately e.g. by a soil layer.

5.2.1.3. Gas

The organic components in the landfill body decompose to landfill gas analogously to an anaerobic biological reactor. The landfill gas consists mainly of methane and carbon dioxide. One tonne of waste produces approximately 250 m^3 gas.

Landfill gas can cause the following detrimental impacts::

- physical effect, explosion,
- inconvenience effect, odour

- toxic, health-endangering effect (for example vinyl chloride)
- contaminating effect
- impairment of the plants growing due to toxic effects or repression of oxygen from the ground.

5.2.1.4. Odour

At disposal, odour emissions originate by different sources:

- odours emitted directly while trucks are unloading and during waste operations on the landfill
- odorous substances in landfill gas causing considerable inconvenience.
- leachate contains numerous odorous compounds, which emit odour when leachate is exposed to the atmosphere.

5.2.1.5. Impact on groundwater

A release of leachate to the groundwater may present several risks to human health and the environment. The release of hazardous and nonhazardous components of leachate may make an aquifer unusable for drinking-water purposes and other uses. In groundwater they may also present a danger for aquatic species. Once leachate is formed and is released to the groundwater, it will migrate downward and contaminate the soil.

Control. Monitoring wells at landfills allow to monitor the contaminants and their movement into the local groundwater system. The wells are placed downgradient of the landfill at appropriate depths and at various intervals.

Fig.56.Sanitary landfill - groundwater wells
www.montgomeryal.gov

5.2.2. Principal requirements for landfills

The standards and regulations for landfill barriers differ in the each country. The following chapters describe the necessary technical requirements and regulations for sanitary landfill technology in Germany and those of the Commission of the European Communities.

To prevent and reduce the potential dangers and emissions from landfills, modern landfill systems are designed on the basis of the "Multi-Barrier-System". This system consists of a set of barriers designed to prevent unacceptable and un-reparable damages to the environment, even if one of the barriers breaks down. The main barriers are the following:

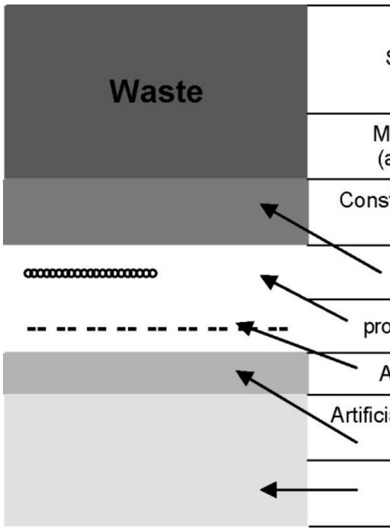
- **Location, geological and hydrogeological conditions**
  In siting landfills, the geological, hydrological and geographical features must be chosen to restrict / inhibit the export of pollutants. The optimum local geological material is low permeability clay.

- **Landfill body, waste pre-treatment**
  The "composition" of the landfill body is the main factor for determining which pollutants which can be emitted from the landfill at all. The risk potential of a landfill is determined by the presence and the mobility of the pollutants in the waste disposed. The aim should be that pretreated waste which has similar properties to the surrounding natural soil forms the bulk of the landfill body. Pretreated waste, with no or small proportions of organic components, prevents or reduces the risk potential of leachate and the formation of landfill gas.

- **Leachate collection and treatment**
  Through the collection and appropriate treatment of leachate the risks of contaminated leachate reaching the ground water, the soil or the surface water regimes are significantly reduced.

- **Gas collection and treatment**
  The collection and treatment of landfill gas (for example for energy recovery or, as a minimum, flaring) reduces the risk of uncontrolled gas emissions.

- **Landfill base sealing system**
  The landfill base sealing system is a technical barrier designed to protect the soil and ground water. The base sealing system is also designed for the controlled drainage and collection of leachate.

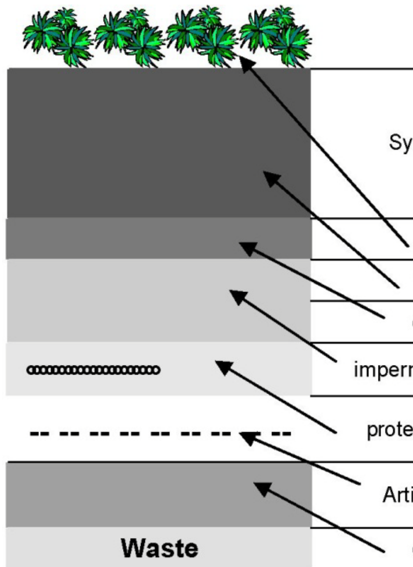


System component	Landfill Category: inert waste	non-hazardous waste	hazardous waste
Material requirements (assessment criteria)	very strictly	strictly	low
Construction requirements of landfill	low	mean	very strictly
drainage layer	not required	d>0,5 m	d>0,5 m
protective layer (Option)	not required	Option	Option
Artificial sealing liner	not required	required	required
Artificial established geological barrier -Option-	not required	If geological barrier not sufficient: d>0,50 m / $k<5*10^{-10}$ m/s	
geological barrier	$k<1*10^{-7}$ m/s d>1,0 m	$k<1*10^{-9}$ m/s d>1,0 m	$k<1*10^{-9}$ m/s d>5,0 m

Table 18: Landfill base sealing system as required by the EU

- **Surface sealing system**

  The surface sealing system is designed to prevent the infiltration of rainwater into the landfill body, as well as the uncontrolled release of gases and odour. The surface seal also minimizes erosion and the dispersion of waste. Following landfill closure the surface sealing system is one of the main barriers as it can be controlled and easily repaired.



System component	Landfill Category: inert waste	non-hazardous waste	hazardous waste
vegetation	Option		
top soil cover	not required	d>0,5 m	d>0,5 m
drainage layer	not required	Option	Option
impermeable mineral layer	not required	required	required
protective layer (Option)	not required	If geological barrier not sufficient: d>0,50 m / $k<5*10^{-10}$ m/s	
Artificial sealing liner	$k<1*10^{-7}$ m/s d>1,0 m	$k<1*10^{-9}$ m/s d>1,0 m	$k<1*10^{-9}$ m/s d>5,0 m
drainage layer	not required	not required	not required

Table 19: Landfill surface sealing as required by the EU

- **Aftercare**

  Following closure, the landfill body of sanitary landfills will remain active for long periods, even if the waste was pre-treated before landfilling. Landfills must therefore be monitored for a minimum of 20 years following closure, including regular inspection of the surface sealing system for damage, inspection of leachate treatment installations and gas collection systems for continuous and orderly operation, and - importantly - monitoring of the quality of groundwater in surrounding areas.

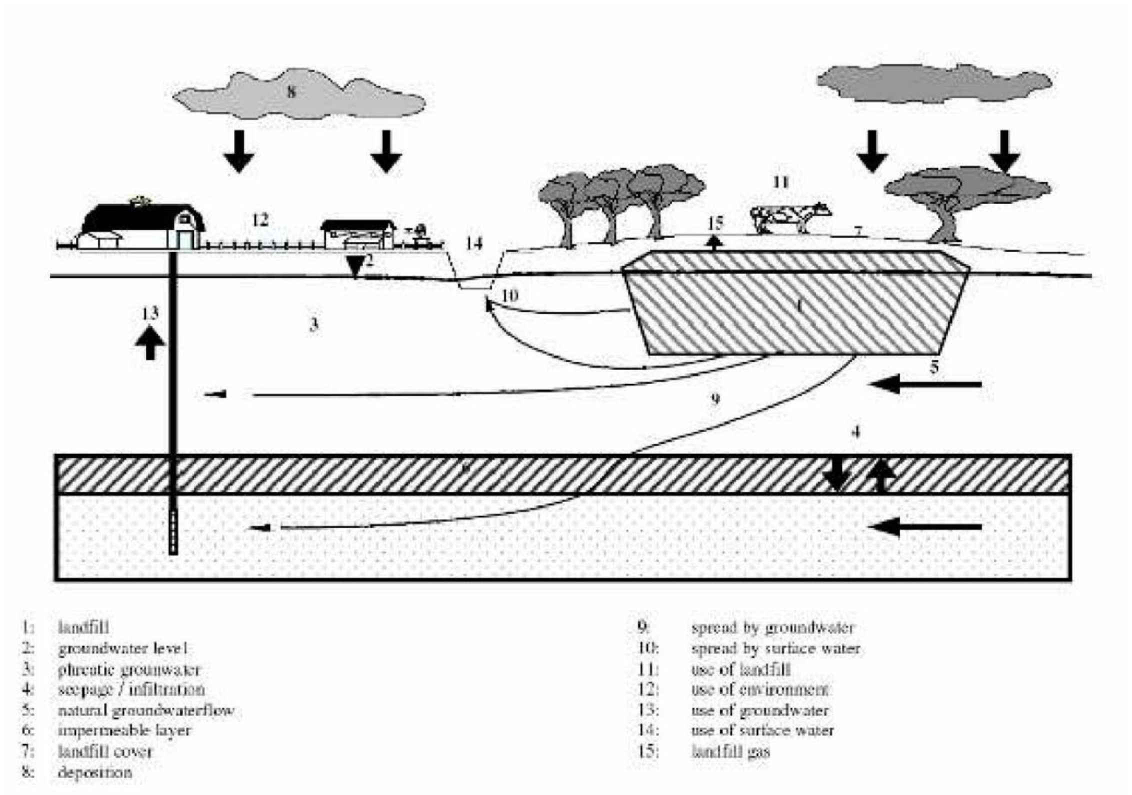


Fig. 57. Potential environmental pollution from closed (restored) landfills sites. Source: Van Vosson, W. (2005). Aftercare of landfills, overview of traditional and new technologies

6. Chapter 6. EU REGULATIONS

6.1. Waste Prevention

In the EU one of the main principles of waste management is that waste generation must be prevented[2]. This principle can be implemented e.g. in production processes. Alternative materials should be used whose environmental impacts are lower than the impacts from the original materials. It should also be a basis of production to produce products that are repairable even if this is contrary to economic principles. The waste prevention principle can be also integrated in the step of product packaging. Practices such as wrapping a product in three different packaging layers are unnecessary. In addition, prevention principles can be implemented at the household level e.g. by choosing products in the supermarket with little or no packaging, and by handling things carefully to use them more than once instead of discarding after first use.

The main focuses of the European waste prevention programs are:

- The formulation of a more ambitious objective for the European waste management policy, i.e.: consolidating and reducing waste generation in accordance with the principle of prevention.
- The creation of a specific chapter on prevention in the Directive 2006/12/EC that devotes it as the first priority of a hierarchy for waste management.
- Quantitative prevention targets
- The development of indicators to measure the evolution of waste production
- The establishment of a European framework for prevention, through an eco- production policy
- The rapid adoption of prevention programs by Member States.

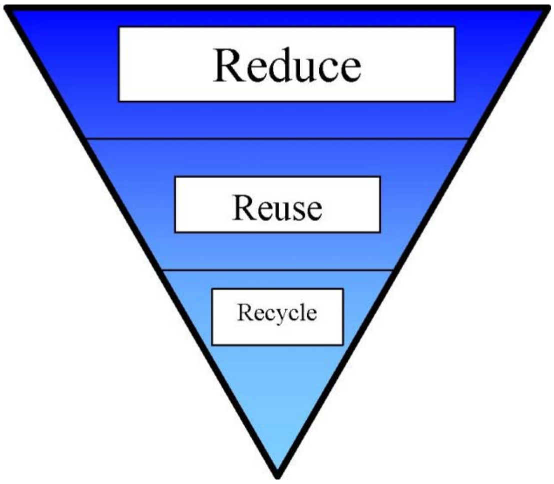
Commission Communication of 21 December 2005 "Taking sustainable use of resources forward: A Thematic Strategy on the prevention and recycling of waste"

6.2. Waste HiErarchy: The 3 R's (Reduce Reuse Recycle)

The principle of Reducing waste, Reusing and Recycling of resources and products is often called the "3R's".

Reducing means choosing to use things with care to reduce the amount of waste generated.
Reusing involves the repeated use of items or parts of items which are still usable.
Recycling means the conversion of a waste to form a new product.

Waste minimization can be achieved in an efficient way by focusing primarily on the first of the 3Rs, "reduce," followed by "reuse" and then "recycle". The principle of *Reduce Reuse Recycle* can be depicted as an inverted pyramid. The pyramid illustrates that the more that waste is reduced, the less must to be reused. And the more that waste is reused the less must be recycled. These are the core ideas of the 3R- principle:



In Europe the waste hierarchy refers five steps in the article 4 of the Waste Framework Directive: prevention; reuse and preparing for reuse; recycling; other recovery, e.g. energy recovery; and disposal. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

According to the Waste Framework Directive the European Waste Hierarchy is legally binding except in cases that may require specific waste streams.

6.3. The Council Directive on Waste

The Council Directive on Waste [3] provides the framework and sets goals for waste management in EU member states. The directive is still in a process of amendment but some targets have already been adopted as follows:

- Waste management plans should be drawn up in the member states
- By 2012 reduction in the total annual quantity of waste generated to 2008 levels
- By 2020 50% of municipal waste and 70% of the construction and demolition waste has to be recycled
- By 2015 systems for separate collection must be established for the following waste streams:
    - Paper
    - Metals
    - Plastics
    - Glass
    - Textiles
    - Biodegradables
    - Oil residues
    - Hazardous waste

- By 2008 the Commission has to present a proposal for a 'Biowaste Directive'
- Waste incineration plants should not receive recognition as recycling facilities unless showing high energy efficiency (60 or 65% this percentage of the energy content of waste must be recovered as heat or electricity).
- The European Parliament concluded to base the Directive on a waste hierarchy:
  1. Prevention
  2. Minimisation
  3. Re-use
  4. Recycling
  5. Energy recovery
  6. Disposal

Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste

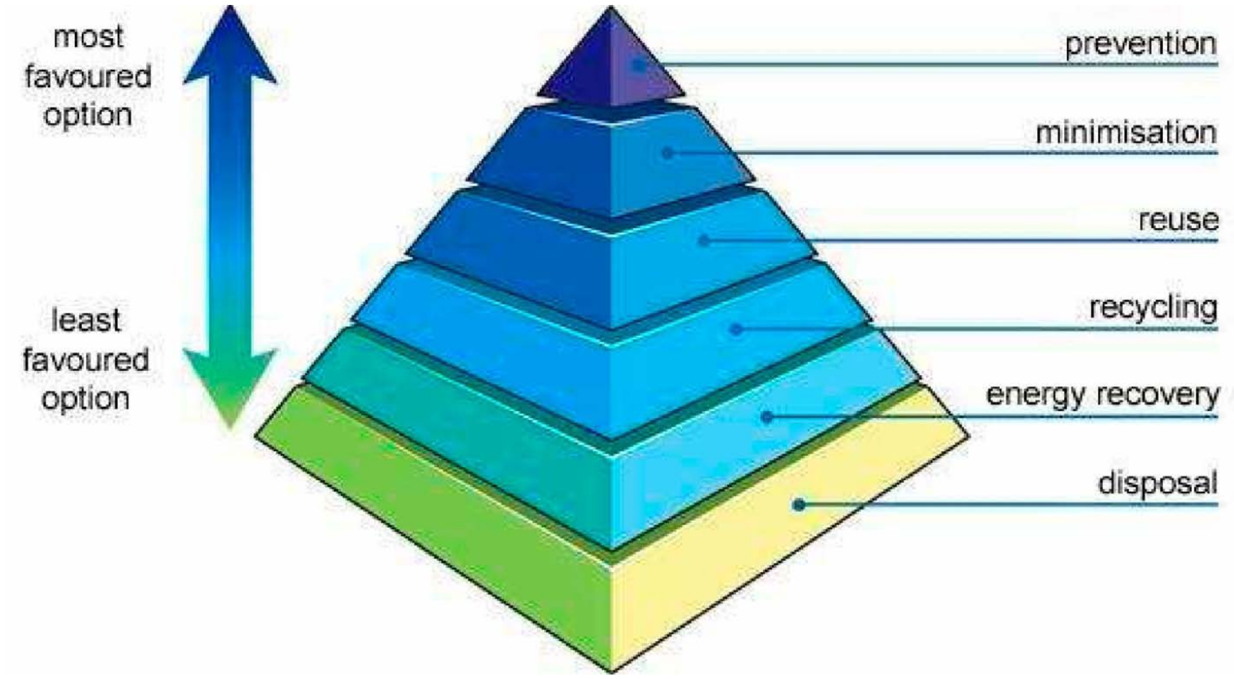


Fig. 58. The hierarchy for waste management

This hierarchy extends that defined in the "3 R" principle, but can be understood similar. Again the pyramid is used to symbolize priorities within the hierarchy.

6.4. The precautionary principle

The precautionary principle 4 seeks to induce reflecting, sustainable and aware behaviour. Where there is a lack of knowledge of consequence, extent or risk of possible damage events, decisions should be based on prevention of such events.

The precautionary principle may be applied where urgent measures are needed to prevent a possible danger to human, animal or plant health, or to protect the environment where scientific data do not permit a complete evaluation of the risk. It may not be used as a pretext for protectionist measures. This principle is applied mainly where there is a danger to public health.

6.5. Integrated pollution prevention and control: IPPC Directive

The IPPC Directive 5 imposes a requirement for industrial and agricultural activities with a high pollution potential to have a permit which can only be issued if certain environmental conditions are met, so that the companies themselves bear responsibility for preventing and reducing any pollution they may cause.

6.6. Environmental liability – Directive

The Environmental Liability Directive [6] aims to make those who are causing damage to the environment (water, land and nature) legally and financially responsible. By implementing a '*polluter pays*' principle in this way the directive should ensure that environmental damage is repaired at the expense of the polluter, rather than the taxpayer. This should create a strong incentive for operators to avoid environmental damage in the first place.

This is the first legislation whose main objectives include the application of the "polluter pays" principle. This directive establishes a common framework for liability with a view to preventing damage to animals, plants, natural habitats and water resources, and damage affecting the land. The liability scheme applies to certain specified occupational activities and to other activities in cases where the operator is at fault or negligent. The public authorities are also responsible for ensuring that the operators responsible take or finance the necessary preventive or remedial measures themselves.

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[4] Communication from the Commission of 2 February 2000 on the precautionary principle

5 Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control

[6] Directive 2004/35/EC of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage

6.7. Waste management statistics

The European Union is establishing a framework for the production of Community statistics on the generation, recovery and disposal of waste [7]

The availability of regular, comparable, current and representative data on the production, recycling, re-use and disposal of waste is essential if the implementation of the Community waste management policy is to be monitored effectively.

In establishing a framework for the production of Community statistics on waste management, this Regulation guarantees the comparability and availability of statistics collected by the Member States.

The Regulation requires the Member States and the Commission, in their respective fields of competence, to produce statistics on:

- waste production
- recovery and disposal of waste
- import and export of waste

6.8. The Multi Barrier Landfill Concept

Historically landfills have been the most economical and environmentally acceptable method for the disposal of solid wastes. Fig. 3 illustrates the *landfill,* an essential component of every waste management system, and its two main emissions, *landfill gas* and *leachate.*

Apart from being odorous, with the potential to reduce residential amenity, landfill gas predominantly consists of methane, a potent greenhouse gas. Leachate contains a range of toxic substances including persistent organic pollutants. Leachate has the potential to pollute ground water reserves thus rendering them unsuitable for human consumption. Both emission types (gas, leachate) can be captured and treated through technical measures (e.g. combustion of landfill gas with and without energy recovery). It is noted however, that landfill gas cannot be fully captured which is one of the reasons for the relatively new solid waste management principle adopted by the European Union (see box below).

For the past 10 years, the European Union has been working towards a reduction (and ultimate elimination) of biodegradable substances from waste prior to disposal to landfill because these materials are the principal source of landfill gas and leachate.

[7] Regulation (EC) No 2150/2002 of the European Parliament and of the Council of 25 November 2002 on waste statistics

Fig. 59. illustrates how this important principle fits with existing safeguards that were developed earlier. Each barrier (safeguard) in the figure represents one step in the chronological development of sanitary landfills during the last thirty to forty years in highly developed central European countries. The Caucasian member states of the Council of Europe have, for example, implemented the first two safeguards at the most.

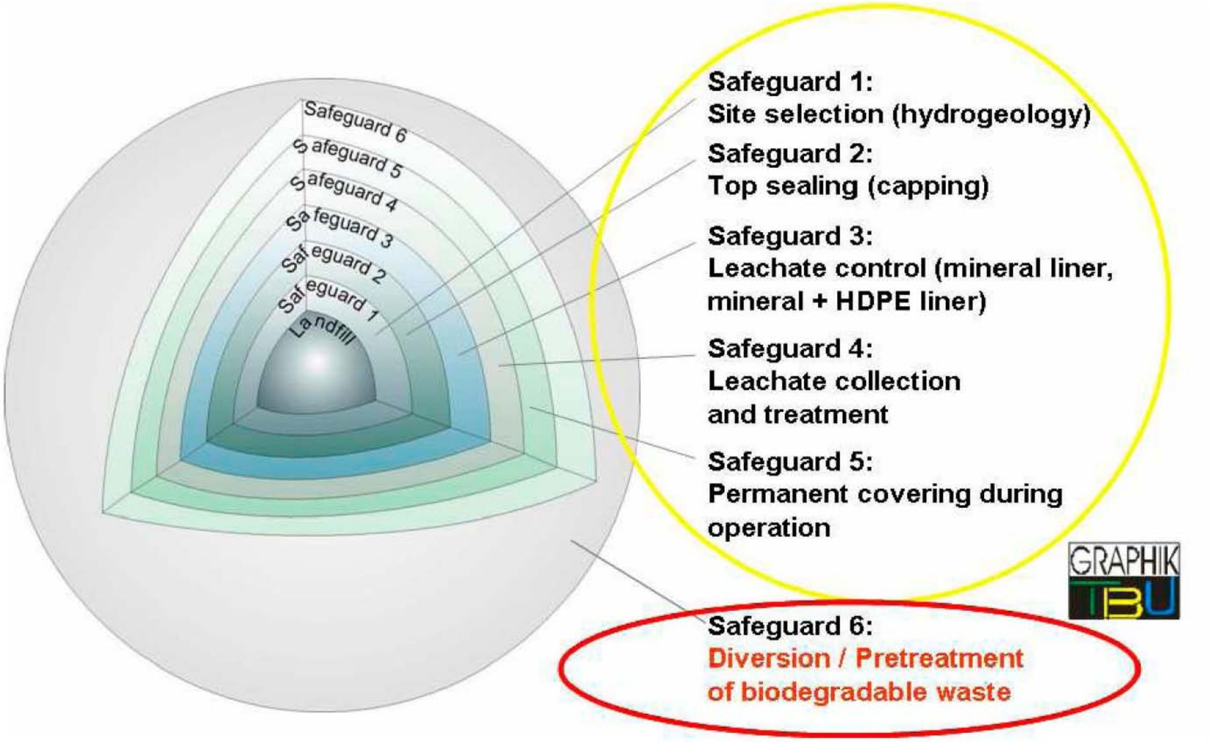


Fig. 59. The Multi-Barrier System for sanitary landfills

6.9. Reduction of biodegradable waste components

Municipal solid waste (MSW) consists of about 60% organic material. This fraction is a perfect medium for micro-organisms. Under anaerobic conditions, such as in a landfill, these organisms degrade the organic fraction basically into organic acids and methane. The methane is on the one hand and odorous, climate-relevant gas but on the other hand it is also flammable which therefore is dangerous to the people who work or live in the area of a landfill. The organic acids are able to mobilize contaminants such as heavy metals that result in a very toxic leachate for which purification is highly challenging and expensive. For these reasons the reduction of biodegradable waste components in MSW is a fundamental measure to avoid long-term problems and costs in operating landfills.

Following the definition in chapter 1 biodegradable waste is any waste that is capable of undergoing aerobic or anaerobic decomposition. Examples include food waste and garden waste as well as paper. Biodegradable wastes form part of household and ICI waste, or are separately collected.

As mentioned above biodegradable waste is a major contributor to the generation of leachate, landfill gas, odour and other nuisances in landfills. Alternative treatment methods such as composting or anaerobic digestion, if properly controlled, can eliminate or significantly reduce the polluting and emission potential of biodegradable waste.

In 1995, about 107 million tons of biodegradable municipal waste were generated in the EU and Norway, of which 66 % was landfilled.

The *"EU Landfill Directive"* imposes strict targets for the reduction of biodegradable municipal waste that may be disposed of to landfill, namely a reduction to 35 % by 2016 of the amounts going to landfill, from 1995 levels. Source separation, separate collection, more incineration, more composting and limits and bans on landfilling are among the key instruments needed to reach this target.

This Directive contains a *phased implementation of reducing biodegradable materials* ("Safeguard 6") as illustrated in Fig. 60.

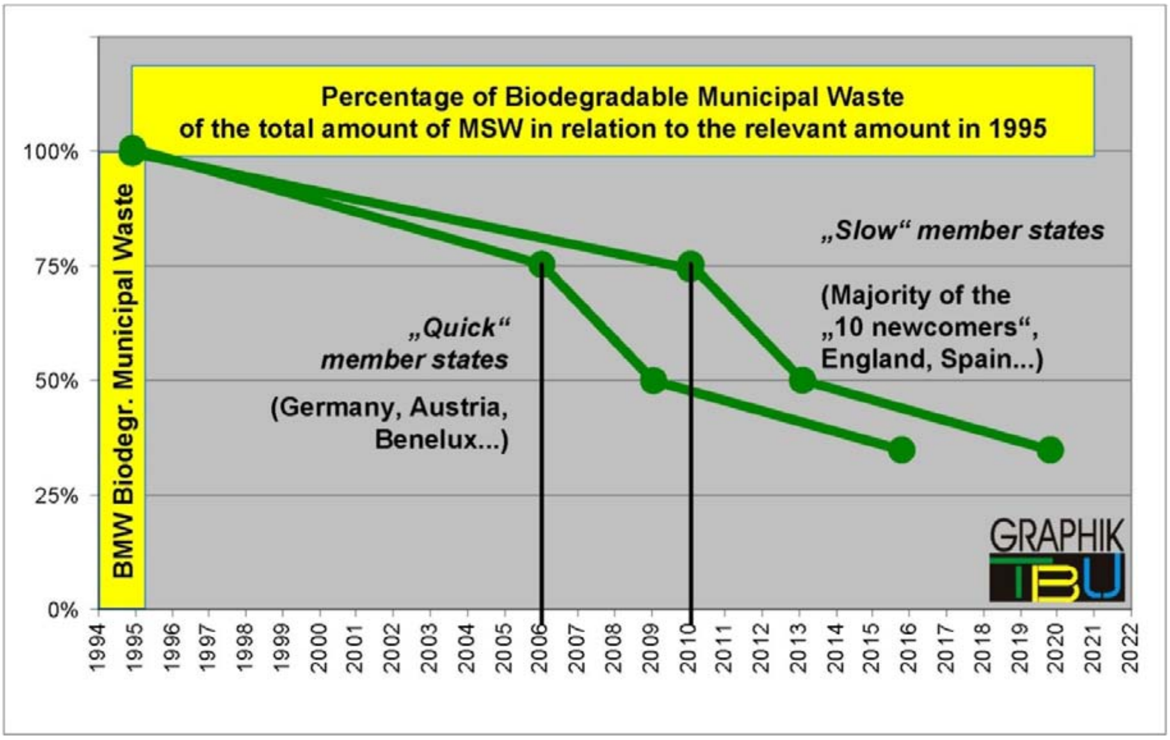


Fig. 60. Targets given by EC Directive No 1999/31 („EU Landfill Directive")

6.10. Overview on the MSW relevant EU regulations

Table 20 gives an overview on the most important directives and regulations that are in force in the EU and related to MSW.

Keyword	Directives or Regulation
General, statistics and transport	
Waste	2006/12/EC
List of wastes	2000/532/EC
Waste statistics	(EC) Nr. 2150/2002
Shipments of waste	(EC) Nr. 1013/2006
Treatment	
Incineration of waste	2000/76/EC
Incineration of **hazardous waste**	94/67/EC
Landfilling of waste	1999/31/EC
Special Kinds/Components of waste	
Batteries and accumulators	2006/66/EC
Waste electrical and **electronic equipment**	2002/96/EC
Restriction of the use of certain hazardous substances in electrical and **electronic equipment**	2002/95/EC
End-of-life vehicles	2000/53/EC
Management of waste from **extractive industries**	2006/21/EC
Hazardous waste	91/689/EEC
Packaging and packaging waste	94/62/EC amended by Directive 2004/12/EC
Disposal of polychlorinated biphenyls and polychlorinated terphenyls **(PCB/PCT)**	96/59/EC

Table 20: Overview on EU directives and regulations related to MSW

7. Chapter 7. WASTE MANAGEMENT IMPLEMENTATION: HOUSEHOLD, ORGANIC, INDUSTRIAL AND CONSTRUCTION WASTE CONCEPT

7.1. Household waste concept

The success of any household waste concept can be measured by its degree of *acceptance,* both for desired separation activities and the associated costs. This can only be achieved by broad scale *information dissemination about the environmental risks* caused by the current management practices, and on how citizens can and should participate in solving these problems.

Community Motivation is fragile. A major priority for waste administrators is to ensure that systems operate as intended, e.g. any material separated by citizens for recycling is actually recycled. Otherwise hard-fought motivation can break down immediately, if people learn for example that a promoted, separately collected recyclable material is remixed with the normal waste.

At a household level, the range of appropriate measures for a modern waste management concept can be summarized as follows:

- Installation of a regular waste collecting system, thereby avoiding indiscriminate dumping
- separate collection of groundwater-contaminating hazardous wastes at households and small enterprises (oil, batteries, accumulators)
- encouragement of home composting
- introduction of separate collection of materials, the value of which easily to be recognized by citizens, such as paper, glass, textiles and metals. As a first step "bring" systems can be introduced (centralized containers).
- installation of a regular, stable fee paying system for waste services

If a separate collection system for recyclables is to be introduced, it should not be implemented at full scale immediately, but first as a *pilot project,* involving some thousand people. The pilot project should be introduced in an area where success can be expected. For *technical* reasons, such a pilot project provides the opportunity to learn about unforeseeable factors, these being useful when expanding to a broad scale collection program. In terms of *motivation,* positive outcomes from a pilot project conducted in a well-known *neighbourhood* are far more effective than simply stating that such recycling programs work well in other countries hence they will work well in the area concerned.

Fig. 61. shows an example of a well-run program of separate collection (based on the results of a suburban area in Germany). This is quite typical for suburban areas in the Middle of Europe where such collections are provided. Here the recycled *quantities* are very high, as most people have their own garden (much biowaste) and read newspapers. The key objective in general is not to recover

high quantities of recyclables, but to lower the amount of remaining waste (in the present case to below 180 kg/year, including bulky waste).

As outlined in Organic waste concept, the introduction of separate collections of recyclables must be appropriate to the type of dwellings present, the existing recovery potential of recyclable materials in the affected waste streams and the existing waste reduction activities in the different dwelling structures.

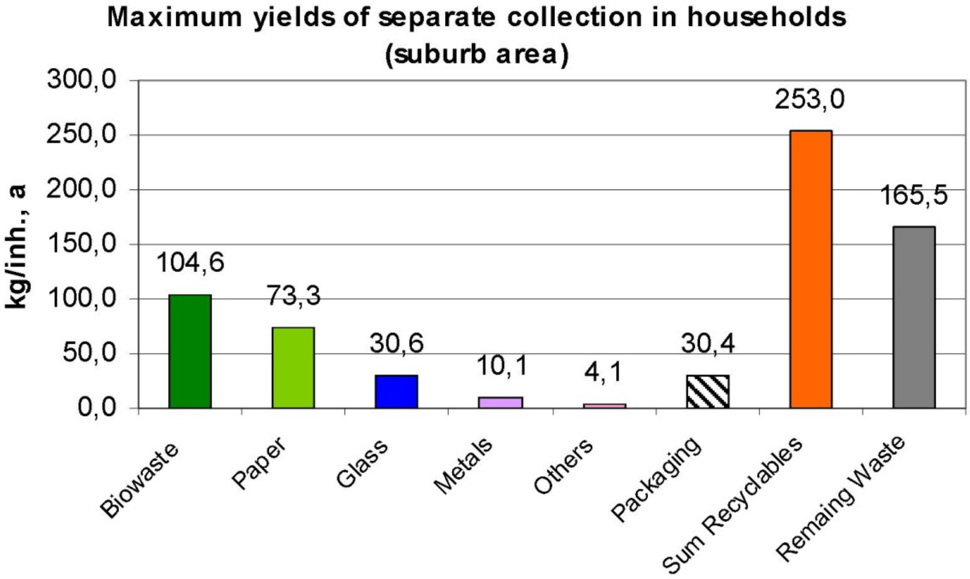


Fig. 61. Maximum yields collected separately (Germany, suburb area)

It should be stated that for the acceptance of a user pays fee system the fee amount should take into account local economic circumstances. As a general rule, the waste fee should not exceed 1 - 2 % of the net income of affected households. This level has been found to be acceptable in most countries. Fig. 62. shows the relation of waste fees compared to expenditure on other, common household items in Berlin, Germany.

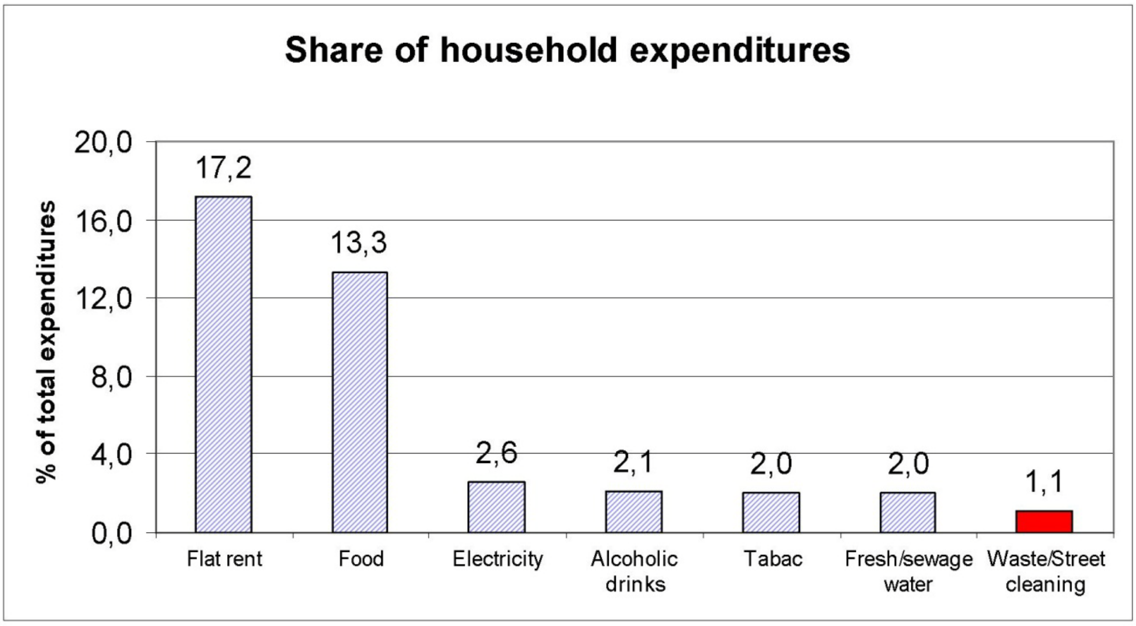


Fig. 62. Waste fee (Berlin) in relation to other typical expenditures of German households

7.2. Organic waste concepts

As indicated earlier, biodegradable organic material forms the biggest single component of municipal solid waste. Organic material can be converted into a nutrient rich product with a range of properties required to maintain and enhance the fertility of agricultural soils. When separately collected and converted to compost (either directly or via anaerobic treatment) these needs can be met without endangering soil quality from heavy metal contamination. On the other hand, when disposed of to landfill as part of mixed solid waste, biodegradable organic matter harms the environment through production of methane, a key contributor to global warming, as well as producing acidic leachate, mobilising heavy metals from other waste components and contaminating surrounding ground water.

A reduction concept for organic waste is presented below taking account options available and different organic waste generation characteristics for different dwelling structures.

The options to recycle and reduce biodegradable fractions in waste include: Measures for separate collection and treatment of:

- Municipal green yard waste
- Paper/cardboard
- Organic kitchen and garden waste ("biowaste")
- In rural areas: Supporting home composting and feeding of animals with kitchen and garden waste.

Measures for treating the remaining mixed **waste through:**

- Incineration
- Mechanical/biological (and thermal) treatment.

The reduction effect, applicability and costs of these measures depend mainly **on the type of dwelling structure.** Those can be characterized as "Inner city", "Suburbs" or "Rural" Areas.

Fig. 63. provides an overview of the existing organic waste situation (here for the example of Bulgaria) for the three different dwelling structures. Fig. 64. shows the impact of alternative measures for organic waste recovery for each dwelling structure. It is clear from the figures that no single set of activities for organic waste recovery is appropriate for all dwelling structures.

Origin of biodegradable waste (Part I and II)

The vast majority of organic waste has, and will continue to be, sourced from urban areas. In the order of 80% of total organic waste is generated in urban areas (comprising inner city areas and surrounding suburbs). This is due to both the higher population of urban areas as well as the lower proportion of organics in wastes sourced from rural areas.

I Population Data

	Population 2010	Inner City 52 %	Suburbs 21%	Rural 27 %
TOTAL	7.500.000	3.900.000	1.600.000	2.000.000

II Amounts of biodegradable waste

Biodegradable fractions kg/cap/year including commercial and other municipal waste	Inner city	Suburbs	Rural
	220	180	85
Contribution to Total Biodegradable-Mass	64 %	22 %	14 %

III Existing Reduction Activities

	Inner city	Suburbs	Rural
Established **backyard composting**	no	low - middle	high
Paper use for heating	no - low	low	high

Fig. 63. Organic waste situation for different dwelling structures

IV Activity options

Activities for ...	Inner city	Suburbs	Rural
Separate collection of **garden waste from public parks etc.**	high	middle - high	middle
Separate collection of **paper**	high	high	middle
Separate collection of **bio-waste**	no	high	no
Motivation campaign to increase **backyard composting**	no	middle	high
Treatment of **MSW by MBT**	high	middle	low

Fig. 64. Effects of different measures to recycle or reduce organic wastes

Existing reduction activities (Part III)

Home composting and animal feeding play an important role in management of organic waste in rural areas, accompanied by burning of paper.

In cities with central heating systems, almost no paper and wood are burned, thus increasing the amount of paper in the waste stream. Home composting is of little relevance in the inner city. In the suburbs home composting can, in principle, be applied, but has been observed that following the trend to more convenience, organics are increasingly diverted to the household waste stream.

Activity options (Part IV)
This is a coarse review of the main options to reduce biodegradable fractions in waste, estimated with respect to their applicability in the different structures. The effect of each activity on reducing organic waste is assessed for each dwelling structure according to its relative cost and impact on organics recovery rates.

Some examples of biological treatment within a waste management concept are provided in the following chapters.

7.2.1. Collection of municipal green yard waste

Green yard waste comprises organic residues arising from public parks, cemeteries, street trees (leaves and pruning) as well as from private contractors maintaining the gardens/park areas of their clients. The operational advantage of this organic waste stream is that it has already been separately collected.

Composting of this waste stream can be implemented as an effective initial measure in cities. Here, composting is quite simple, since green yard waste does not create as many emissions as e.g. biowaste. Such a composting program can be accompanied by general restrictions on delivery of green yard waste and/or manure to the landfill sites. Separate areas for unloading of green yard waste should be provided at the entrance to each landfill. Depending on the local dwelling structures, the system can be extended by providing centralized containers for garden wastes from private households.

Quantities recovered depend on the amount of green areas within each dwelling structure. In general, green waste quantities for cities can be assumed to be in the range of 25 - 30 kg/cap./year.

7.2.1.1. Stabilization of home composting

Experience has shown that providing separate biowaste collection services in rural areas results in an increase in total organics generation, with little change to the quantity of organics present in collected MSW (typically 30 kg/cap./year). The main task in rural areas is therefore not a reduction of organics - since maintaining the *status quo* would already be a success. However, experience has also shown that organics generation increases even in rural areas with improved economic conditions. Motivational campaigns in rural areas are therefore needed to maintain home composting and animal feeding practices.

The recent contribution of home composting to the reduction of organics in rural areas is presented in the following example:

The "generation rate" of garden waste is in the order of 1 - 1.5 kg/m^2/year, thus the generation from a 800 m^2 garden is roughly 800 kg/year, which equates to 200 kg/cap./year for a 4 person household. We can roughly add another 60 kg of kitchen waste, giving 260 kg/cap./year of organics. Nonetheless, recent audits have shown that only 10 % of this amount appears in the household waste, meaning that **home composting [8] shows a reduction rate of 90 %**. This is more than can ever be expected from any separate collection system, and this reduction is produced solely by **traditional behavioural practices of the rural population.**

Measures to stabilize and encourage this behaviour are:

> Information campaigns;
> Support through provision of home and on-farm composting systems;
> Support by a flexible fee system (as a future option).

Information campaigns should be primarily focused on increasing awareness of the population that indicate, apart from recycling (whose benefits are better understood), any avoided kilogram of organics from the waste stream provides environmental benefits, particularly for ground and surface waters. The general knowledge on the impacts of waste on nature and the environment is based on the belief that organics do not cause any negative impacts as they are "natural" and biodegradable (while "artificial" products such as plastics and glass are often considered to be more dangerous in landfills). Information should be provided on the negative impacts of organics in landfills (on leachate quality, mobilisation of heavy metals by organic acids, production of methane, etc.) in an understandable way, thereby demonstrating that home composting and/or animal feeding is not only of direct benefit, but that all owners of gardens and animals have a responsibility to keep organic waste away from landfills.

Support through provision of home composting systems **is primarily estimated as a gesture by municipality for the** high appreciation of home composting. **In** research projects undertaken in rural and suburban areas of Germany (around Munich, 1990) it was found that residents from "urban" areas in particular, who had settled outside the inner city areas in single unit dwellings, commenced home composting because they received a free composting bin. Their share of the whole population was between 5 - 10 %. Overall, 15 - 25 % of households took a "free" compost bin, and indicated that they increased composting.

Fig. 65.Home composting example

"Home composting" here is a synonym for a not precisely definable "treatment-mix" of composting, animal feeding and - at a smaller scale - burning of wood and paper in stoves.

7.2.1.2. **Biowaste collection**

For several decades during the 20th century mixed household waste has been composted in many countries (e.g. Spain, Turkey). At these facilities, technical means were employed to separate the organic fraction from other waste components. Despite technical progress in refining the compost product it was not possible to completely remove contaminants. The concentrations of heavy metals in the compost remained high, threatening soil quality when applying this kind of compost. Separate collection of food waste and green organics (biowaste) by the generator was recognized to be the only way to produce "clean" compost.

On this basis, organic waste collection programs have been established separate to mixed waste collections. Paper and cardboard can be added to the organic waste fraction without endangering the compost quality, especially if the printing inks are almost free of heavy metals. Of course, the specific properties of the paper fiber are lost by this way of recycling, so the collection of paper as a separate, single fraction is generally preferred.

Since the mid 1990's the separate collection and utilization of biowaste forms part of waste management practice in almost all German, Austrian, Swiss, and Dutch municipalities, and about 40 % of Italian municipalities.

Separate collection of biowaste (and also paper products) has and will continue to contribute significantly to reaching the set targets.

In terms of amounts and quality of biowaste collection, there are differences when looking at the three main types of dwelling structures:

- **A)** **Inner city** - Multi-unit dwellings (mainly without gardens)
- **B)** **Suburbs** - Single unit dwellings (mainly with gardens)
- **C)** **Rural areas** - Small villages and single houses

Each person roughly produces 70 kg/year of organic kitchen wastes (remainders of vegetables and fruits, coffee, soiled paper, etc). In areas with attached gardens, an amount of 1 kg/m^2/year must be added.

Organic waste generation characteristics of the different dwelling structures are described below:

Structure A) - Inner city, multi-unit dwellings:
These dwelling types are typically characterised by low organic waste generation, shared bins between dwellings, higher fluctuation in waste generation, differing degrees of education, lack of social control.

The higher the number of families living in a building which uses centralized bins for separation, the lower is the quality of the separated recyclables / biowaste within them.

Another option for biowaste collection from inner city areas is to establish commercial collections in areas with high concentrations of restaurants, canteens, food shops, etc. This can be organised by providing the restaurants and food shops with biowaste containers for separate collection of food waste.

Experiences from biowaste collection programs in inner city areas e.g. in the inner city of Berlin (similar to the collection of biowaste in other inner cities) indicate the recovery rate of organics is roughly 30 %, or 20 kg/cap./year. Typically about 30 % of the inhabitants are active participants who collect and separate almost 100 % of their organics with high purity, while the remaining 70 % of inhabitants do not participate. A key objective of biowaste collection in inner city areas is to prevent non-participants from throwing their mixed household waste into the biowaste bins. Fig. 66. shows the yields of biowaste collected in various German cities. The differences in the quantity of collected biowaste between cities are mainly due to varying percentage of suburban households included in the data.

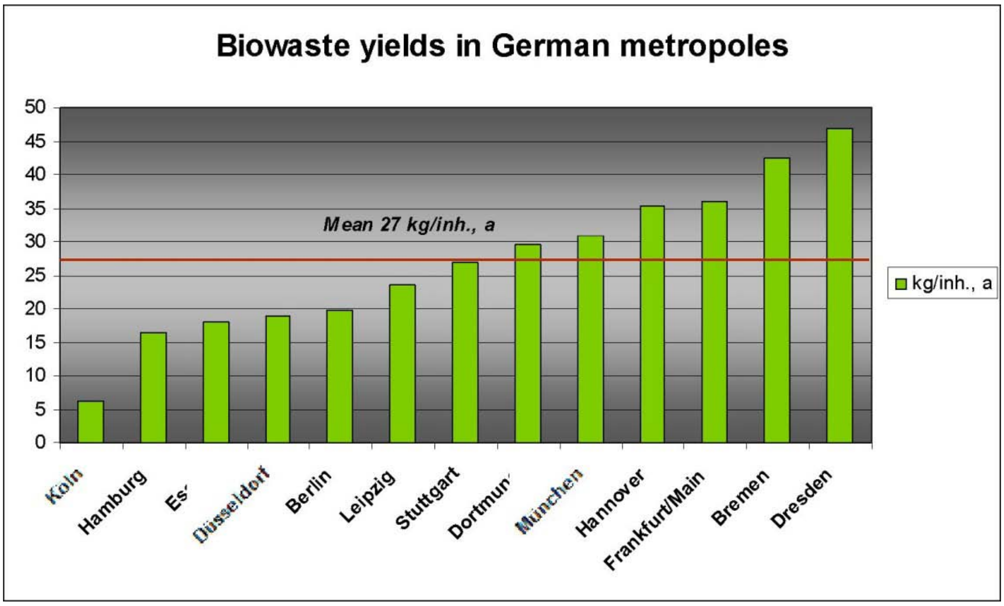


Fig. 66. Yields of biowaste (collected in wheely bins = "green bin", "biowaste bin") in various German cities (> 500.000 population)

Fig. 67. Biowaste collection Structure B) - Suburban Areas, single unit dwellings

These dwelling types are typically characterised by high organic waste generation, individual bins per household, lower fluctuation in waste generation, differing degrees of education, higher social control.

People living in single unit dwellings with their own garden generally have a higher awareness of nature, soil, plants, compost and nutrients, making them more open to the idea of biowaste collection and the production of compost. Some garden waste is usually home-composted, but home composting in suburban areas does not reach the level of that carried out in rural areas - at least half of the produced organics are found in the household waste, equating to about 100 - 120 kg/cap./year. Biowaste collection can reduce this amount to 30 - 40 kg/cap./year. Practical experience has shown that introduction of biowaste collection reduces home composting activities. The impact is such that roughly each kilogram of reduced organic in the mixed waste is accompanied by almost another kilogram of formerly home-composted organic waste. 100 kg of collected biowaste thereby correspond to 50 - 70 kg reduction of organics in the mixed waste.

Structure C) - Rural areas

As already mentioned, the amount of organics in the waste from rural areas is already very low due to highly efficient home-composting practices. Installation of biowaste collection would likely recover home-composted material with a negligible effect on the organics in household waste. As long as home composting maintained at current levels, there is no need to introduce a separate collection of organics in rural areas.

The sketch on page 90 gives an overview on the status of biowaste utilization in the European countries.

The methods of treating of biowaste are previously described.

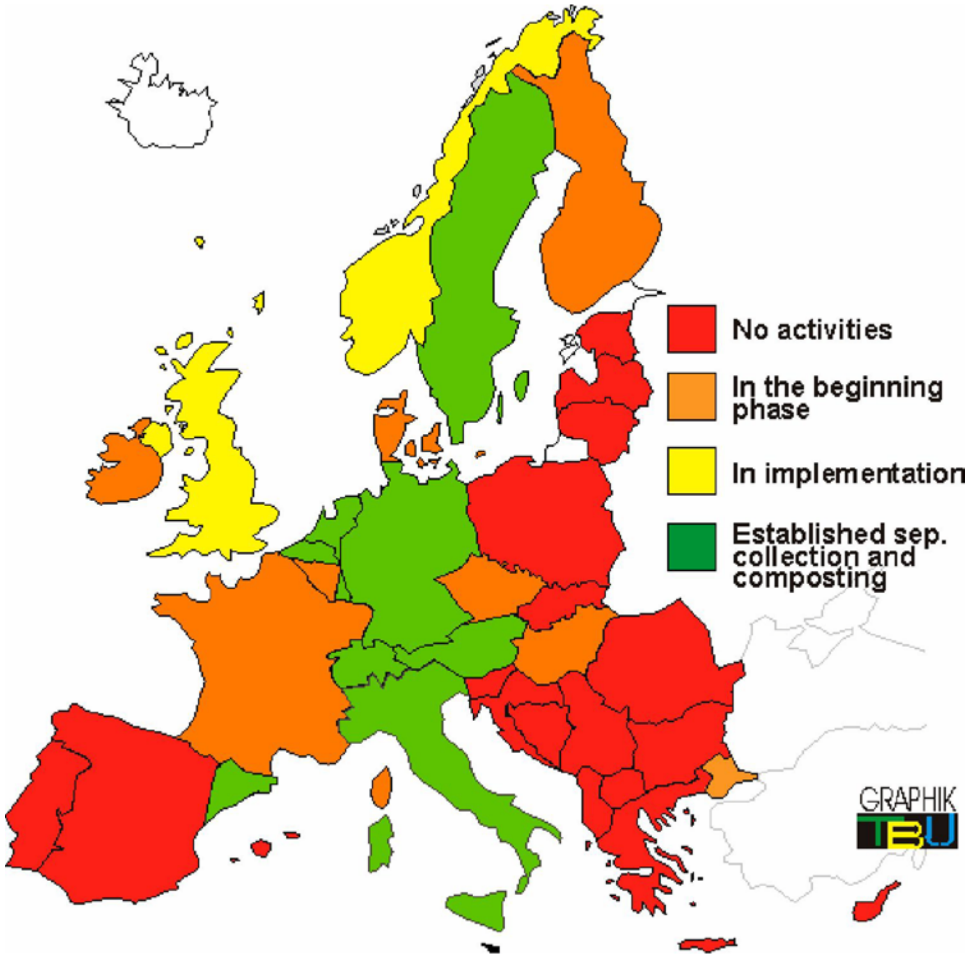


Fig. 68. Status of separate collection & biowaste utilization in European countries (status 2004)

7.3. Concepts for Industrial, Commercial and Institutional waste

<u>Origins of ICI-Waste</u>

Industrial, Commercial and Institutional Waste (ICI-Waste) show a much broader variety in their different origins compared to household waste. Each country is obliged to collect data from the different branches of industry and commerce about the quantity of waste and the degree of recycling. An example for the origin of ICI by sector is shown in Table 21 (for England).

Sector	Sector Description	Total thousand tons/year	share
	Industrial Waste		
1	Food, drink and tobacco	7.230	19,2%
2	Manufacture of textiles, wearing apparel, leather, luggage, handbags and footwear	1.234	3,3%
3	Wood and wood products	1.471	3,9%
4	Manufacture of pulp, paper and paper products	1.822	4,8%

5	Publishing, printing and recording	2.174	5,8%
6	Production of coke, oil, gas, electricity, water	6.182	16,4%
7	Manufacture of chemicals and chemical products; cleaning products, man-made fibres etc; rubber and plastic products	5.257	14,0%
8	Other non-metallic mineral products	2.272	6,0%
9	Manufacture of basic metals	4.815	12,8%
10	Manufacture of fabricated metal products	1.525	4,1%
11	Manufacture of machinery and equipment	939	2,5%
12	Manufacture of office machinery, computers, electrical, radio, television and communication equipment; medical and optical instruments and clocks	515	1,4%
13	Manufacture of motor vehicles and other transport equipment	1.475	3,9%
14	Furniture and other manufacturing	675	1,8%
	Total Industrial Waste	**37.587**	**100,0%**
	Commercial and Institutional Waste		
16	Retail - motor vehicles, parts and fuel; wholesale; other retail	12.753	42,1%
17	Hotels, catering	3.352	11,1%
18	Transport, storage, communications	2.182	7,2%
19	Travel agents, other business, finance, real estate and computer related activities	7.150	23,6%
20	Miscellaneous	1.554	5,1%
21	Social work and public administration	1.390	4,6%
22	Education	1.939	6,4%
	Total Commercial and Institutional	**30.320**	**100,0%**
	Total ICI waste	**67.907**	
	kg/ per person and year (49,5 Mio Inh.)	**1.372**	

Table 21: ICI - Waste from different branches, example: England 2003.

Source: http://www.defra.gov.uk/environment/statistics/waste/alltables.htm#figures

The information presented in Table 20 is based on a survey conducted by the by the UK Environment Agency. Information collected for each business included the type of waste, quantity of waste, the waste form, waste disposal or recovery method. Data collection was limited to controlled waste and relates to England only. The estimate of industrial waste includes power station ash, blast furnace and steel slag.

In 2002/3 Industrial and Commercial waste in England totalled 68 million tonnes. Of this about 38 million tonnes was attributable to industry and 30 million to commerce. The sector that produced the most waste was the retail sector, which generated nearly 13 million tonnes of waste. This was followed by food, drink and tobacco manufacturing, and the professional services and other businesses, both producing more than 7 million tonnes.

As shown in Fig. 69. in the case of England, more than half of the waste is recycled or brought to energy or other recovery systems.

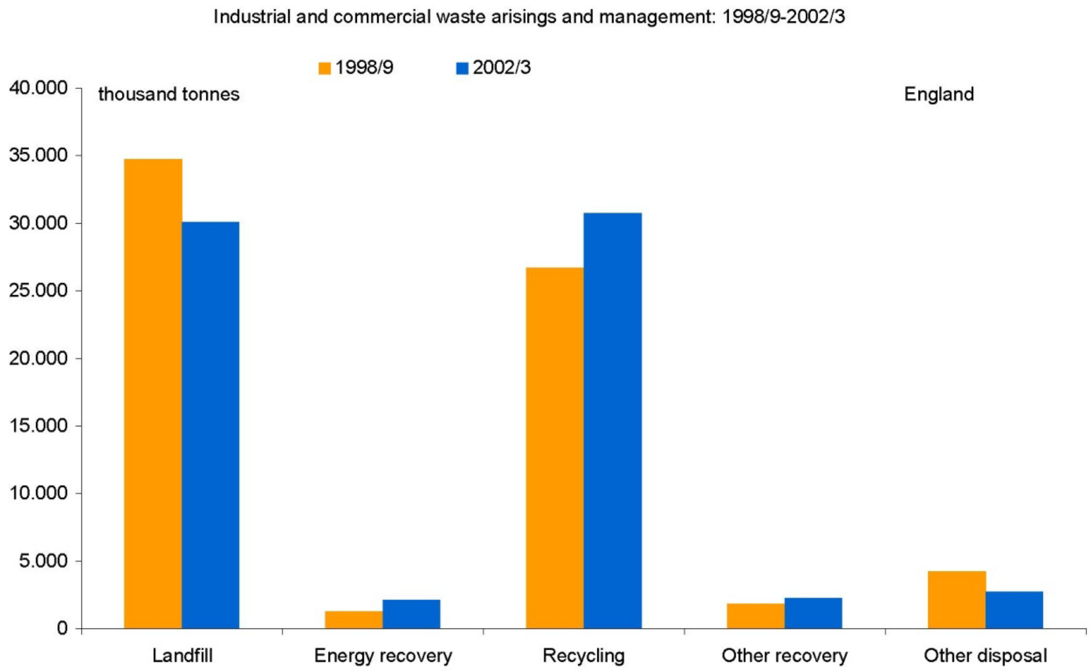


Fig. 69. ICI waste arising and management: England 1998/9-2002/3

The consistency of waste differs of course by the type of sector being considered. A summarized overview, again for England, is given in Fig. 70.

A finer categorization of industrial waste is implemented in the European Waste Catalogue, which covers a huge number of specifications following the very different waste types, especially concerning hazardous wastes.

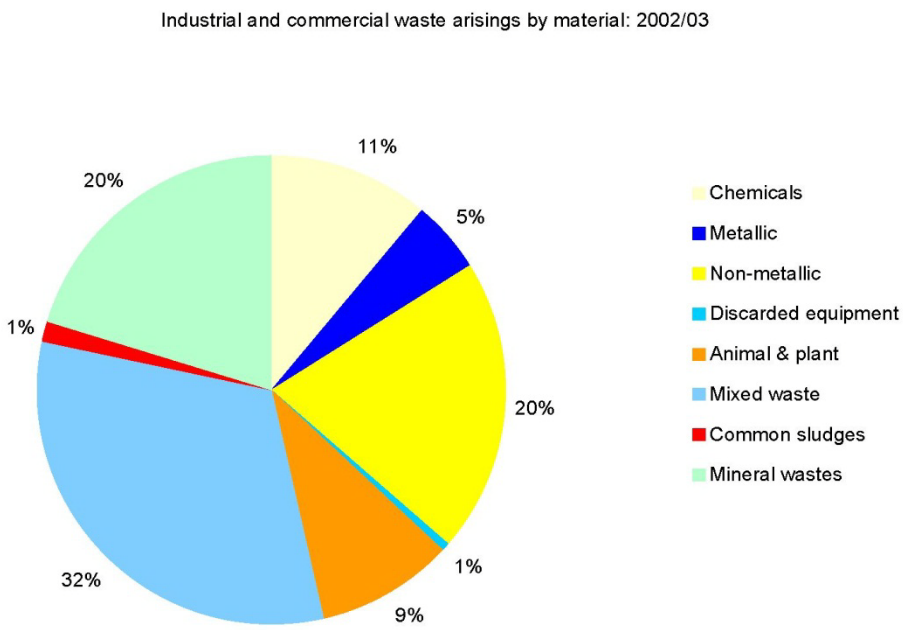


Fig. 70. Compounds of ICI-Waste (as originated, before e.g. recycling measures)

Concepts on ICI-Waste

As described in Table 20 waste management systems for ICI-Waste can be roughly divided into two main categories:

a) The mixed waste (share 32 %), which, when combined across sectors, is similar in nature to household waste, with the main components of paper, cardboard, packaging, organics etc.
b) The production specific waste (almost the rest), coming from the specific production system

Category a) waste can be assessed in a similar manner to household wastes: Separate collection systems can be introduced for different streams as is practiced in the broader community. A similar level of education and motivation needs to be provided to staff handling waste as for the general community, e.g. to the cleaning personal on how to handle the separated fractions.

For the production-specific Category b) fractions a solid investigation must firstly be carried out to determine at which process step which kind of waste occur in which amounts.

For many businesses and factories significant cost savings are achievable through waste reduction activities. These often go unrecognized. Waste reduction practices not only conserve resources and protect the environment, but can be very profitable to the business in the following ways:

- Substantial cost savings by reducing waste disposal costs and material purchase costs.
- Cost savings associated with reduced product defect rates and improved process quality.
- Reduced liability by eliminating disposing of waste in the landfill.

- Potential revenues from material recycling.
- Good public relations tool.

The general principles for a business waste reduction plan are:

- Selective configuration of the processes such that rejects/residues are minimized
- Minimizing and strictly separated collection/storage of hazardous waste
- Keeping separate residues from other potentially recoverable substances thereby maximising the possibility for internal and external recycling
- Development of a logistic/operational system for collection and storage of recyclables
- Monitoring of market and re-user's conditions for recyclables
- Incorporation of waste prevention into the production quality management.
- Compliance of the concept with national and EU-regulations

In general, for any kind of business, the easiest first step is the reduction of disposed packaging waste which can be achieved by:

- agreements with the supplier to take back packaging material and/or to reduce packaging of the delivered goods
- Using rechargeable containers for the supplier's and the business' own products
- Separate collection of the main packaging materials such as cardboard.

Influence of EU, National law and municipalities on ICI-recycling

The European framework outlining duties for recovery of packaging materials are set out in the EU Directive 94/62/EC of 20 December 1994 on packaging and packaging waste amended by Directive 2004/12/EC. Some national legislation relating to ICI- Waste specify that minimum recycling rates for specific components of the ICI-Waste are obligatory, or a nationwide fee for landfilling is imposed increasing the disposal costs for these wastes, thereby providing strong economic incentives for the commercial sector to increase avoiding and recycling of waste fractions.

The municipality can increase the incentive situation by:

- increasing the fee for the disposal of waste
- excluding recyclable charges from disposal (this only working with recycling opportunities in the region)
- informing the enterprises of options for reducing and recycling.

Concepts for ICI-Waste might differ in their appearance and technical design, however the basic rules previously highlighted are applicable everywhere.

Fig. 71. Concepts for commercial waste: Solid waste management on ships.

Right photo shows a waste collection station on a Greek ferry under Maltese flag connecting Italy and Albania.

7.4. Construction and Demolition Waste concepts

Construction and demolition waste (C&D waste) makes up approximately 500 - 1.000 kg per capita and year, therefore representing two to five times the quantity of household waste. A large proportion of C&D waste originates from the demolition and renovation of old buildings. It is made up of numerous materials including concrete, bricks, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled in one way or another. Waste quantities per capita vary considerably from one country to another. This can partly be explained by the economic and cultural differences that exist between countries, the size of the agglomeration (city or village) partly by the statistical definition, e.g. whether excavated soil is included or not, or whether large infrastructure projects (e.g. a railway tunnel, a harbour extension) are included.

Construction and demolition waste originates from a wide range of activities including construction, development, civil engineering, transport infrastructure, renovation, rehabilitation and maintenance. As a result of these varied activities the composition of these wastes can be very variable.

Measures to prevent the generation of Construction and Demolition Waste and improve the recovery of material for re-use and recycling will substantially contribute to solving an environmental problem and to conserving natural resources. Inappropriate C&D waste management will result in the loss of valuable raw materials, the depletion of resources and the filling up of available landfill space. By examining ways of eliminating or reducing waste, the construction industry can achieve significant improvements in profitability.

Factors which affect the nature and volume of C&D waste include:

- individual family dwellings are predominantly built of blocks, brick and wood, with e.g. wood much more widely used in Scandinavia than elsewhere in the EU;
- the 1950s and 1960s apartment buildings in urban industrial centres in most EU Member States were generally built of reinforced concrete (in contrast to masonry buildings of former years); copper piping replaced lead piping and by the 1980s plastics (especially PVC double glazing units) were becoming widespread in pipes and window frames in all sorts of residential buildings;
- many industrial and commercial buildings erected since the 1980s have benefited from faster construction techniques based on steel frames. The steel- framed structures lack the 'natural' fire resistance provided by concrete and brick, requiring much more fire proofing of beams and columns (often involving hydrocarbon-based materials) and firefighting systems (often involving chemicals which may themselves be hazardous);
- many new city buildings are built with underground parking facilities or underground retail areas, greatly increasing the volumes of soil and rock which must be excavated and removed;
- irrespective of the primary materials from which they were constructed, older buildings are more likely to contain hazardous material such as asbestos or PCBs, because controls on these materials have been tightened over time. In same manner there is a higher potential for contamination of building structures from the products used or made in older industry buildings,
- the trend in fixatives, fillers and coatings has moved from *nails, screws, plaster, mortar* and *emulsion paints* to *organic resins* and *solvent-based products* which, although inert or at least non-hazardous in their final form, are made up on site from components which are often flammable and/or toxic, and whose residues and containers are therefore also potentially hazardous;

It is possible to identify a number of key components which can be expected to occur to some extent in the waste arising from the majority of construction and demolition sites. These are in particular:

- soils and subsoils, excavated fill materials,
- concrete,
- asphalt and bituminous materials,
- bricks and tiles,
- timber (treated and untreated),
- plaster, plasterboards and other internal finishes,
- plastics, metals, glass,

- architecture features,
- mixed debris (delivery packaging, paper, cans, etc.).

7.4.1. European legislation and definitions

Construction and demolition waste has been identified as a priority waste stream by the European Union. This means that particular attention will be paid to policies and measures to ensure increased recycling of construction and demolition waste.

Council Directive 2006/12/EEC is the 'framework' directive for European waste legislation. It contains the terminology and definitions for waste management in the European Union.

Annex 1 of the directive lists categories of waste. Of these a number are of relevance in respect of C&D waste.

The List of Wastes is established with Commission Decision 2000/532/EC of 3 May 2000. It contains about 40 types of C&D waste. Any waste marked in the list with an asterisk (*) is considered as hazardous waste, e.g. asbestos or other dangerous compounds.

7.4.2. C&D waste management

Many of the recommendations and the information in the following sections are based on a report from the Project Group on Construction and Demolition Waste, in the framework of the Priority Waste Streams Program of the European Commission [1] and on a report to DGXI, EC on Construction and Demolition Waste management practices and their economic impacts (Symonds [2]).

In consideration of the hierarchy of waste management practices the chain of construction and demolition waste management generally can be subdivided in the following phases (see flow chart in Fig. 60):

Prevention phase: In the prevention phase (situated at the beginning of the chain) no construction and demolition waste is generated. Nevertheless it is possible by taking measures in this phase, to influence the quantity and the quality of released construction and demolition waste. If the measures concern the quantity of construction and demolition waste than it is a matter of "quantitative prevention"; however if the measures influence the quality of waste, than it is a matter of "qualitative prevention".

Separation phase: In order to be able to realise a high percentage of reuse or to maximise the yield of C&D waste - derived aggregates it is necessary that separation of renovation-, construction- or demolition waste, in partial streams, takes place with consideration of the potential contamination of the materials. The best way is separation of materials at source, predominantly through selective demolition and good management of construction sites. The main partial streams (by quantity) are: soil, stony particles (concrete, brickwork), asphalt, wood, metal and plastics. In practice it is possible that the major part of the construction and demolition waste can be separated or selectively demolished and offered further for treatment.

<u>Treatment phase:</u> In the treatment phase the streams of separated waste (partial streams) are treated in such a way that new materials are generated, which are (in principle) suitable for reuse/useful application. For each partial stream of the treatment phase again different material-streams can be distinguished, e.g. streams of stony particles, asphalt or wood.

<u>Market phase:</u> Decisive for the attainment of the 'reuse' target is the application in the market-phase of the materials, which are produced in the treatment phase. To that end existing markets in the market phase have to be consolidated or extended and other markets have to be developed. With that the application has to be as high-graded as possible.

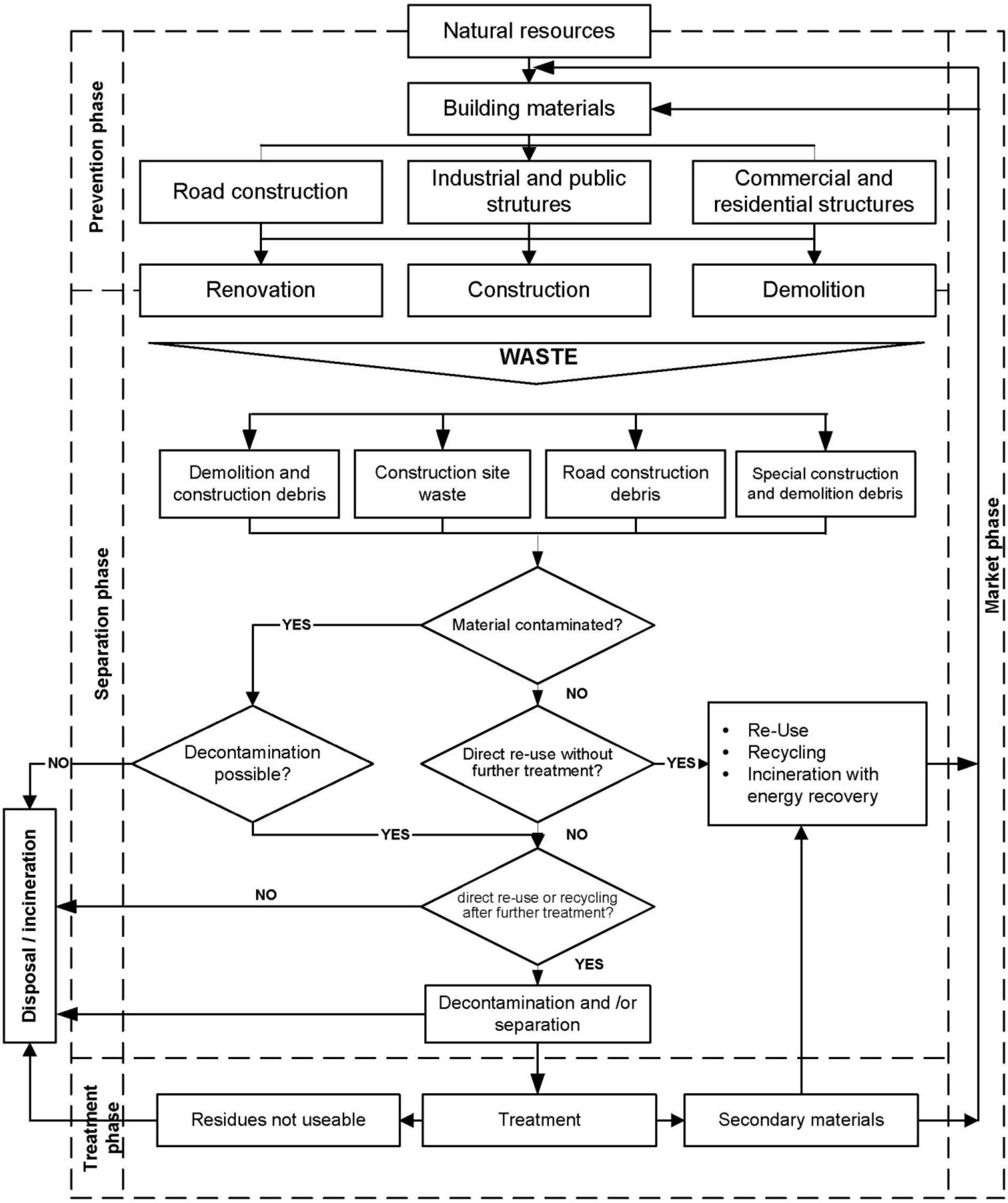


Fig. 72. Construction and Demolition Waste Flow Chart

7.4.3. Measures for improving recovery of C&D waste

7.4.3.1. Construction

Measures to reduce C&D wastes, considering their hazardous potential as well as recycling possibilities can be integrated to appropriate logistics on construction sites during construction or renovation activities.

Contractors should consider the use of non-hazardous materials when choosing materials available on the market.

Where waste from construction is inevitable, there are three options available:

1. sort and separate waste before the waste contractor removes the skips from site,
2. appoint an approved waste contractor to remove unsorted waste for separation at an alternative location, and
3. establish return and collection systems. The economic benefits from selection and sorting on-site depend on the scale of the project. Sorting of waste off-site afterwards can be an economic and environmental alternative.

Fig. 73. Examples of containers / bins for on-site collection

7.4.3.2. Demolition

The demolition industry is one of the most important producers of C&D waste and plays an important role in the proper management of demolition waste. A prerequisite for the optimal recycling of demolition waste is that the demolition industry anticipates - before the demolition process starts - the possibilities for recycling of the material arising. In principle, four levels of techniques must be distinguished:

1) Planning and assessment: a demolition project has to start with an inventory of the material present and the planning of the work with respect to obtaining proper, separated materials.
2) Adequate execution techniques: in order to ensure an optimal isolation of hazardous materials and separation of parts and materials for re-use and recycling, adequate demolition techniques and processes must be applied.
3) Management techniques: the separation of materials on the site, avoiding cross-contamination and the selective application of techniques requires an adequate management of the demolition site and training of the workers.
4) Technical equipment: the application of selective demolition techniques requires suitable equipment in order to achieve the required treatment of the material and the selective proceedings under dangerous and high level risks circumstances.

7.4.3.3. Re-use

Re-use of products is to be encouraged at all times, as this is the most direct way of preventing waste generation. Products such as roof tiles, doors or windows can be salvaged fairly easily. In those cases where demolition sites and construction sites are physically close, salvaging of materials or construction elements should be carried out.

7.4.3.4. Recycling

The main recycling processes are sorting, crushing and screening to produce aggregates for use in civil engineering works, landscaping and e.g. as a substitute for gravel in concrete products. Recycling into aggregates reduces volumes of C&D wastes going to landfill and conserves mineral resources. The major fraction of C&D waste is mineral-based and is used primarily as recycled aggregate for road construction. A number of research projects demonstrate that recycled aggregates can be used for concrete production (high-level reuse). There are also other uses of recycled aggregates as fillers or compounds for other construction materials.

Smaller C&D waste streams, like plastics, wood and metals also need to be addressed. Metals will often be recoverable due to their market value. Wood may be sorted and chipped, rendering it useful for the production of chip-board. Plastics are recyclable only when they are recovered in a clean state. Plastic products, such as expanded polystyrene foam for thermal insulation and PVC tubes and PVC window frames can be collected separately on a construction site and either be re-used or recycled.

Fig. 74. Recycling facility for demolition waste

7.4.3.5. Sorting plants

In several EU member states, C&D waste sorting plants are an integral part of C&D waste management. They can be part of a recycling facility.

Because of differences in EU Member States it is relevant to refer to the levels of technology in the recycling of waste-streams. There are three basic combinations of technologies:

- *Level 1:* mobile crusher and sieving plant
- *Level 2:* level 1 plus metal removal and more complex sorting/sieving
- *Level 3:* level 2 plus hand sorting, washing plant and facilities for other C&D waste streams (wood, etc).

It is important to stress that none of these technical solutions are right or wrong in their own way. The level of technology is in accordance with national, or even local, conditions with regard to the market situation, waste policy etc. In general, in EU- regions where landfill charges are low, 'level 1' is commonly met.

8. Chapter 8. WASTE MANAGEMENT ASPECTS

Each European municipality is responsible for waste disposal and must develop a waste management concept which forms the planning basis for waste-related activities over a period of typically three to five years. The waste management concept must consider the following measures:

- Reuse and recycling of waste components
- Waste collection and transport
- Treatment facilities for the different kinds of waste
- Environmentally responsible disposal of remaining waste

The development of a waste management concept must follow the relevant legal regulations. As a fundamental basis it needs knowledge on quantity and composition of the different waste streams. Fig. 75. illustrates the procedures and elements of a modern solid waste management concept.

The situation of the existing waste management system must be assessed in terms of waste quantity, composition and the collection systems employed. This information characterises the *status quo*.

If the current situation in a country is analysed a national master plan for waste management must be drawn up. This national master plan should be used as a basis to regulate waste management in the future. Waste stream quantities for the following years must be projected for a range of scenarios based on different assumptions.

The final decision on which measures will be adopted is made on the basis of the comparison of the different scenario results. A range of implementation programs are ultimately developed. These can include: a new or adapted user fee system, the installation or optimisation of source separated collection and the corresponding collection infrastructure. Other possible activities could include building recycling plants or waste treatment plants. If there are problems with landfilling a landfill sanitation program could be an option. If the chosen programs require the participation of the citizens, PR measures and training courses can be initiated.

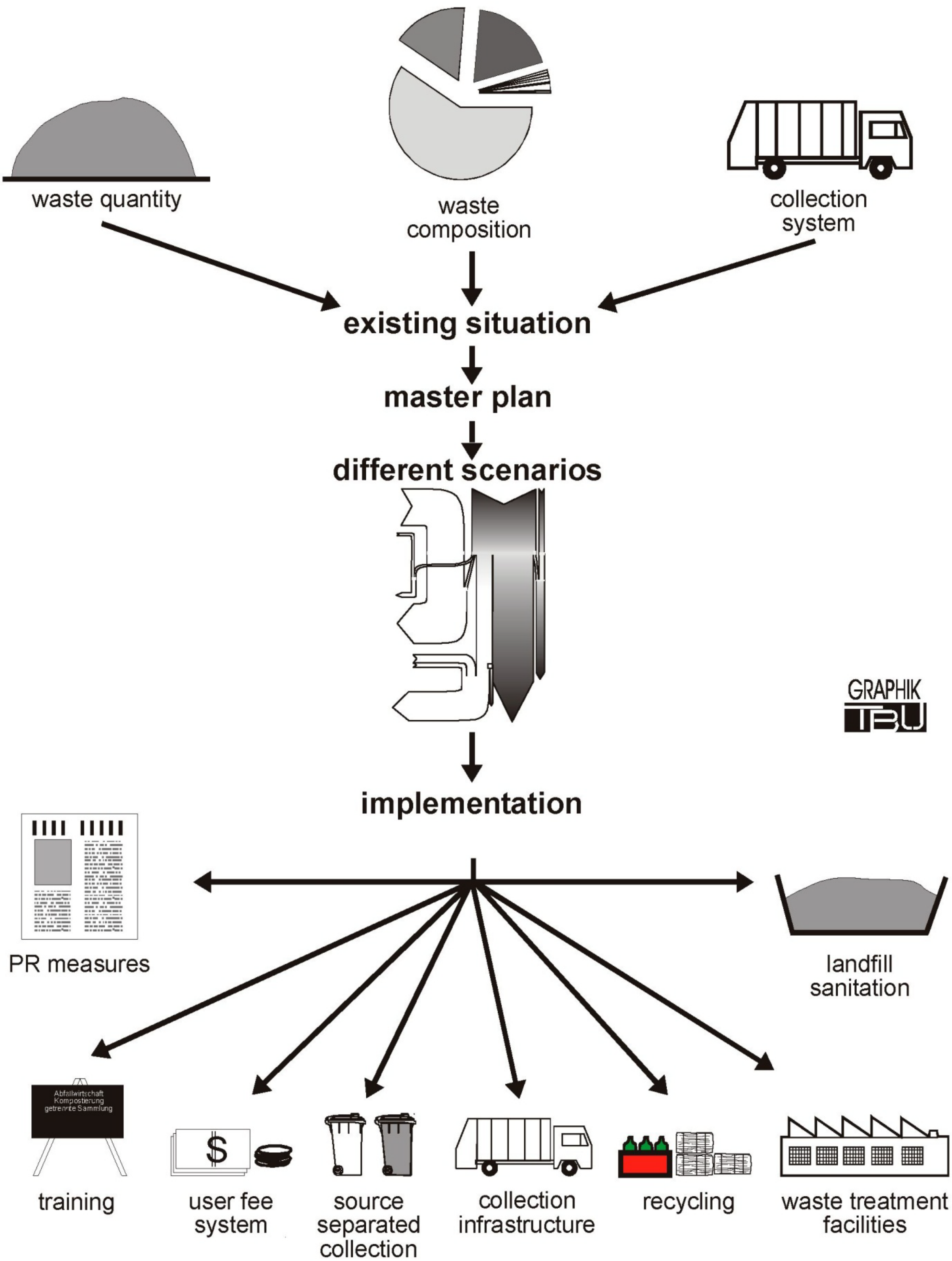


Fig. 75. Procedures and elements of a modern solid waste management concept

8.1. Stepwise development of waste management

Increasingly in Europe waste management is no longer regarded as a solely *technical problem. The importance of involving waste generators in developing and implementing programs has now been recognised.* This shift can be attributed to the fact that the 'purely technical' systems have failed. Industry and regulators have learnt over the last decade that the most effective way to reach established goals and targets is to make distinctions between waste streams and to convince citizens as well as trade and industry to separate waste at its source.

A municipal waste management concept should guarantee the disposal capacity for a minimum of 10 years. The time horizon that should be considered in a waste management concept is therefore one decade. Targets must be stated resulting from the comparison of the legal framework, the current situation and the forecasted waste management system.

The main framework for EU member states is the *'waste management hierarchy'* of the *European Union* and the related directives.

1. Waste reduction

2. Diversion from Landfill

3. Landfill

- Reuse
- Recycling
- Biological Treatment
    - Composting
    - Anaerobic Digestion
- Incineration with Energy Recovery

The general aims of a waste management system are shown in Fig. 76 and implement three main components

- a competent, independent and powerful **administration,** initiating and promoting the relevant activities
- a well informed and motivated **population** (as well as managers in the institutions and facilities) as a basic condition for most of the avoidance and recycling concepts, which can only be realized through their active participation
- a set of "*state-of-the-art*" **installations** to treat the different waste streams in an ecological responsible way

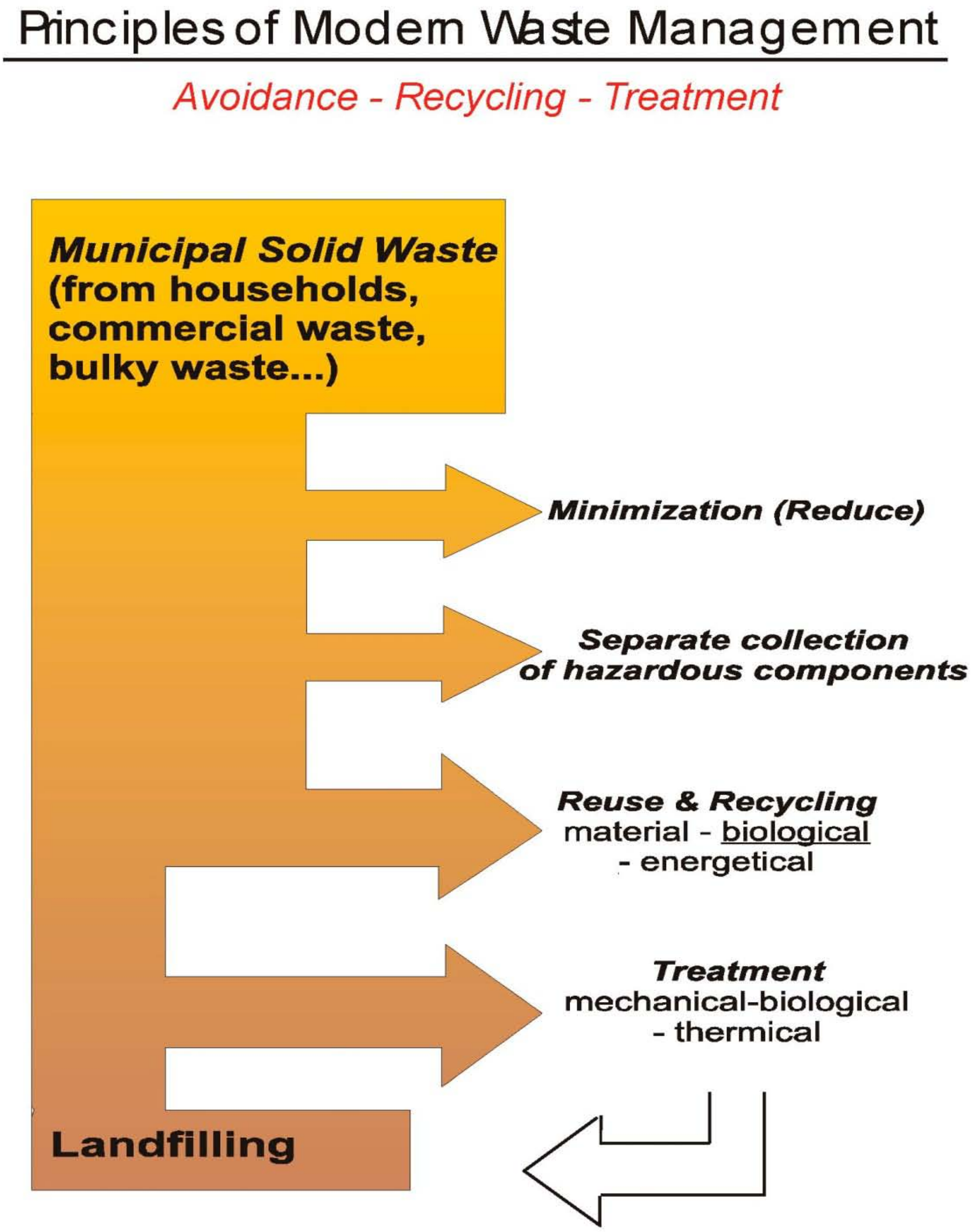


Fig. 76. Principles of modern waste management

The first objective is to prevent the formation of waste. As a next step, efforts should be taken to reuse certain materials and, at the next level of the hierarchy, to recycle as much as possible. Biological waste treatment - composting as well as anaerobic digestion - is also of high importance for a successful waste management system. Finally, waste incinerators are mainly used in densely populated areas where large quantities of waste are produced within a small area. The production of energy can be regarded as a side effect as the mass and volume of remaining residuals are drastically reduced. On landfills solid residuals from incinerators (slags, dust, remnants of gas cleaning) as well as from other waste treatment plants (e.g. coarse fractions from composting plants) are deposited.

A successful 'Waste Plan' aims to reduce waste through minimization and recycling by about 50%. It is generally agreed that this target can only be reached through wide-spread introduction of source separated collection of recyclables and organic wastes. About half of the 40 % 'recycling' potential (in Fig. 77. the recycling potential is the range between the black and the red line for the year 2000) is estimated to be organics recycling (paper represented by the red column and biowaste represented by the brown column).

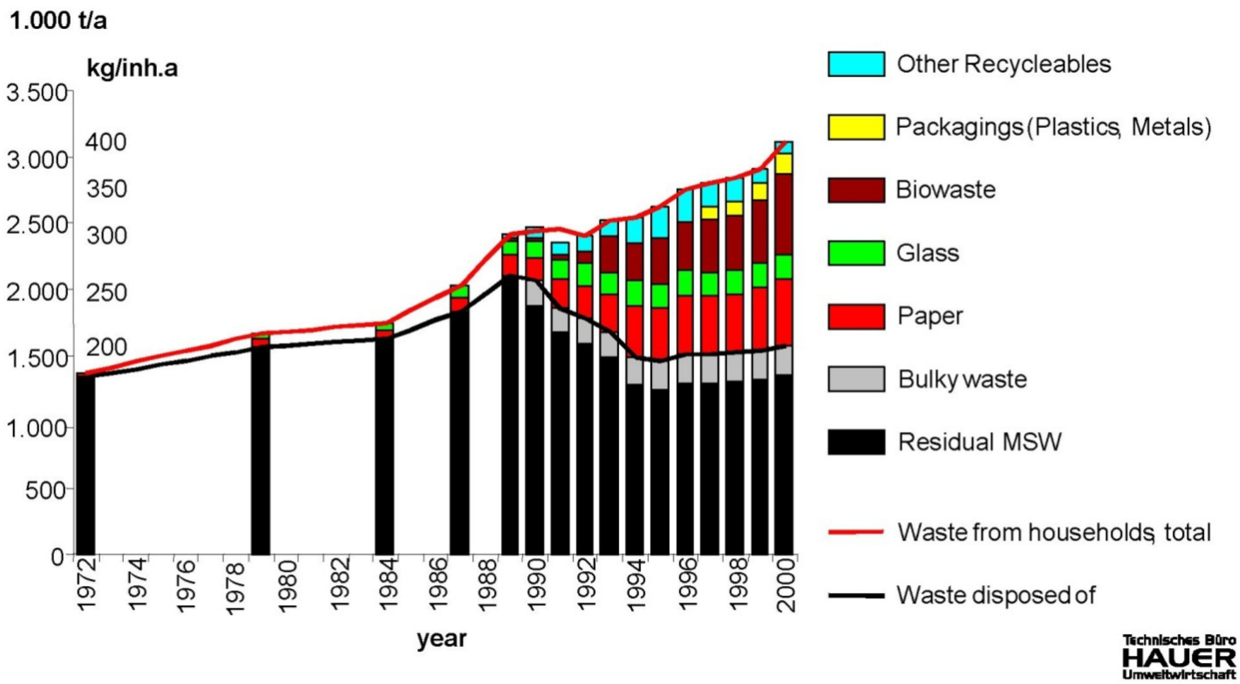


Fig. 77. Example Austria 1972 - 2000: Reduction of waste to be disposed of by 50 %

The steps towards realization are described in the following sections.

8.1.1. Evaluation of the present situation

A detailed analysis of the existing situation serves as a necessary basis for the development and assessment of options targeted towards future improvements.

Quantity and composition of wastes

An assessment of waste quantity and composition yields important up-to-date data against which the impacts of new programs can be effectively measured following implementation. The evaluation must be carried out by well-trained and equipped staff using a hands-on-approach: Existing landfills, industrial producers of wastes, buyers of recyclables of relevant size should be visited, collection vehicles accompanied, and wastes from selected sources sorted manually and sent to chemical laboratories for analysis.

In Austria and Germany a standardized assessment procedure is employed, which comprises a combination of sieving and hand sorting. As a first step, areas representing different socio-economic districts, from which wastes are to be collected for sorting, must be selected and characterized. Data projections based on these findings will lead to more accurate results, as parameters such as the remaining fraction of recyclables in residual wastes depend typically on the motivation of the population, on education levels, and on the nature and extent of built-up areas. Thus a sorting campaign accounts for specific local circumstances that may not be found elsewhere.

Wastes from commercial producers should be analysed with regard to their quality by staff trained in assessing the composition of industrial wastes. These wastes are examined as they are delivered to disposal facilities over several days.

Quantity and qualities of recyclables
The existing quantity of recyclables collected and also of those materials that might be of interest for collection in the future must be assessed, as well as a survey of possible buyers of these recyclables (at a nation-wide level) and of dealers of recyclable materials (at a regional level). Also an overview of existing market prices and their recent development should be undertaken.

Existing collection services
The effectiveness of existing collection services must be assessed, and the additional capacity that can be handled by the existing infrastructure, if any, should be quantified. This is an important preparatory step for the introduction of additional collection programs in the future, e.g. for the separate collection of recyclables and biowastes, which must be handled separately from other residuals from the source of their production in order to maximize end product quality.

8.1.2. <u>Development of the master plan</u>

In the second step goals that are desirable from an ecological point of view and are realistic from an economic point of view are clearly defined. Following this alternative paths towards the realization of these goals are developed based on industry know- how. Certain measures, out of the many that are possible, are then selected. Important aspects which are to be considered during this step are that techniques are well proved in practice and that they are financially feasible.

In the final steps which can last up to several years all the adopted programs of the waste management master plan are implemented:

Organizational elements
Legal regulations have to be established together with training of local experts on implementation of the regulations. Training programs should focus on the practical aspects such as the impact of new regulations on day-to-day work practices and provide trainees with a full picture of what should be accomplished.

Citizens as well as trade and industry should be encouraged to adopt correct handling and separation practices for waste using a range of professional PR techniques. This can be supported by an adapted user pays system which gives economic incentives for the separation of refuse at the source.

Technical elements

Finally the different waste treatment facilities must be established. This step represents the most cost intensive phase of the concept realization.

As an overview a waste management concept for households should include the following topics:

i. Framework and data collection
   a. Legal framework, laws, directives, regulations, principles and resulting limit values
   b. Data collection and balancing
      i. Analysis of the area for which the waste management concept applies:
      ii. Analysis of the disposal arrangements
      iii. Determination of the waste quantity
      iv. Waste analysis
   c. Description of the existing waste management measures
      i. Presentation of all technical measures along the disposal chain
      ii. Description of the waste management logistic
   d. Description of management tools
      i. Waste and fee regulations
      ii. Public relations

ii. Forecast
   a. Analysis of the relevant factors of influence
   b. Development of waste quantity and composition forecasts

iii. Draft concept
   a. Assessment of the waste management situation
   b. Measures of waste prevention
   c. Measures of waste treatment and disposal
   d. Management tools
   e. Assessment of future measures

iv. Catalogue of measures

   The catalogue of measures should include all necessary programs for waste prevention, separation, collection, recycling, disposal and related aspects, as well as the associated timeframes and the responsibilities.

   Depending on the timeframe measures can be categorised as: urgent, medium-term or long-term measures.

   a. Urgent measures
   - closing of illegal landfills and dumpsites
   - public information and education
   - excluding industrial and commercial hazardous wastes from non-secured landfills and providing separate storage areas

- organization of regular waste collection at households
- reduction of groundwater contamination at existing landfills by operating measures (increase of the density of disposed waste, covering of non-operated areas with soil)
- centralized storage areas for old car wrecks and tires

b. Medium-term measures
- separate collection of groundwater contaminating hazardous wastes at households and small enterprises (oil, batteries, accumulator)
- research of the main sources of hazardous waste in the local industries and installation of a specific monitoring and (interim) disposal system
- reduction of the organic component of the disposed waste by separate composting of municipal and commercial green waste and encouraging home composting
- technical optimisation of existing landfills especially in terms of groundwater contamination (leachate capture and treatment systems)
- installation of separate collection systems for glass and paper
- separate collection of refrigerators and electronic devices from households
- preparation and realisation of a tender for waste disposal
- planning and building of a mechanical-biological treatment plant
- upgrading of landfills to the best available technology

c. Long-term measures
- planning and building of an incineration plant, if needed by sufficient waste amounts
- deconstruction of landfills to eliminate further contamination

8.2. Institutional aspects: Who does what?

In a waste management system the appropriate allocation of roles and functions to the various stakeholders is of utmost importance:

1. The responsibility for municipal waste management - collection, disposal - generally rests *with the Municipality.*
2. It is up to the Municipality
   - to provide the relevant services directly, *or*
   - to contract it out.

The tasks of both *setting and collecting waste service fees and charges* should remain with a municipal body. Systems where the waste collector (be it a public or private company) have the dual tasks of collecting the waste and charging fees for the service usually encounter problems as the "power' of a waste collector (again: be it public or private) to recover a money from users is much less than that of a public body such as a municipal administration. Also in economically weaker countries and regions the "affordability" of a waste service fee in social terms is often confused with "willingness to pay" - which can cause problems particularly if the provided service does not meet the expectations of the user. So...

3. the user of the service *(household, commercial premise, ...)* pays for the service *(as a fee)* to the Municipality.

4. *The decision on affordability issues is up to the Municipality,* more precisely: It is the right of the Municipality to waive the fee to debtors who are socially and economically in need of it, but it is not up to the debtor to make such decision.

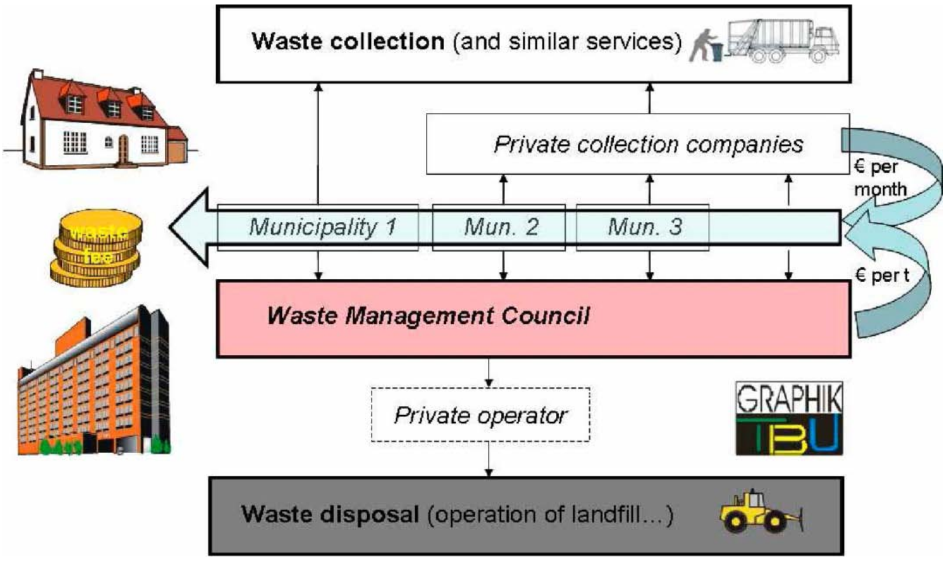


Fig. 78. "Who is doing what ?" (waste collection, disposal, fee management) in an Austrian Province (Western Tyrol Area, 50 municipalities with about 70.000 inhabitants)

5. Certain commercial and institutional waste generators *may take back the responsibility for collection and disposal* from the Municipality. They turn into "self-disposers".

6. The differentiation between

   - 'household waste' (which remains under the Municipality's responsibility in any case) and

   - 'commercial waste' (which might be disposed of independently by the relevant generator, e.g. a supermarket chain) usually is done according to *quality* and/or *amount.*

7. *Collection tariffs* are subject to market competition

8. Disposal (landfill) tariffs *are subject to control / approval by local government as .landfill volume" can be considered as public good.* Note: This last principle can be seen as a basic rule for systems at lower development stages, in more complex systems more refined models may apply.

8.3. How to design a waste fee?

This chapter contains some hands-on advice on one of the most important elements of a solid waste management concept: How to implement the "The User Pays" principle in practical terms? i.e. how to bring the money from the pocket of the user of the system to the account of the system operator.

Some of the basic fee *principles* are presented below, followed by examples of the *types of fees* for domestic waste, including recommendations, and examples from two Waste-Train countries. Basic principles of waste fee systems are:

1. **The User Pays** is a "fee design principle" in itself
2. **KISS** - Keep It Simple Stupid
   - Reduces administration efforts
   - Reduces regulatory requirements
   - Provides transparency, important over the long term.
3. Tariffs should incorporate / represent an incentive to support the system's policy - (which in Europe is the ‘3 R's’)
4. Tariffs fall due on a regular (monthly to yearly) basis
5. No differentiation is made between collection and disposal cost.

Types of fees (for domestic waste) include:

1. Tariffs per *household*
2. Tariffs per *household,* considering also *number of persons*
3. Tariffs based on *floor space*
4. Tariffs based on *volume*
5. Tariffs based on *weight*
6. Tariffs based on *property value*
7. *Tariffs based on* distance to disposal point...

...and combinations thereof (usually 1/2/3 combined with 4/5):

Tariff types 4 + 5 fulfill the objective of providing an incentive to support the system's policy (i.e. to maximise recycling) but: A split-up of the fee in ‘base (fixed) fee’ & ‘top- up (variable) fee’ is recommended, as shown in Fig. 79.

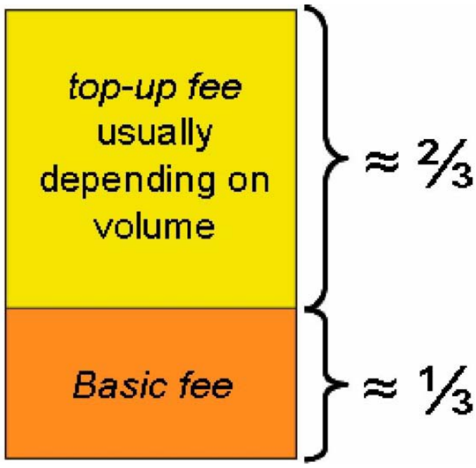


Fig. 79. How to design a fee for domestic waste: typical split-up of fixed & variable fee portion

Some practical hints & comments:

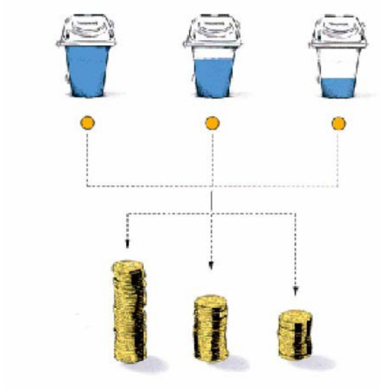
1. Tariffs per *household* do not provide any incentive e.g. to recycle: a family of six produces more waste than a single-person household, requesting the same fee from both households would could be regarded as unjust
2. Tariffs per *household,* considering also *number of persons,* and
3. Tariffs based on *floor space*

are both difficult to administer (due to both limited availability and quality of data!).

4. Tariffs based on *volume*

a) Measuring the produced waste volume ('real volume metering')

b) Counting the emptying of bins ('identification')



c) Pre-paid bags

(a system widely adopted in Switzerland and Austria)

...can be seen as the best compromise between the three conflicting requests for simplicity (keep it simple stupid !) "ultimate fairness" (reason for the next tariff type) and practical feasibility.

5. Tariffs based on *weight* can be highly sophisticated (see left photo above). These can pose practical problems e. g. frozen waste in winter can stick to bins thus is weighed, and paid for, several times, some users incorrectly placing waste in other's bin to avoid cost. Where the weight of a single load can be easily measured however (e.g. commercial loads), weight should always be taken as tariff basis.

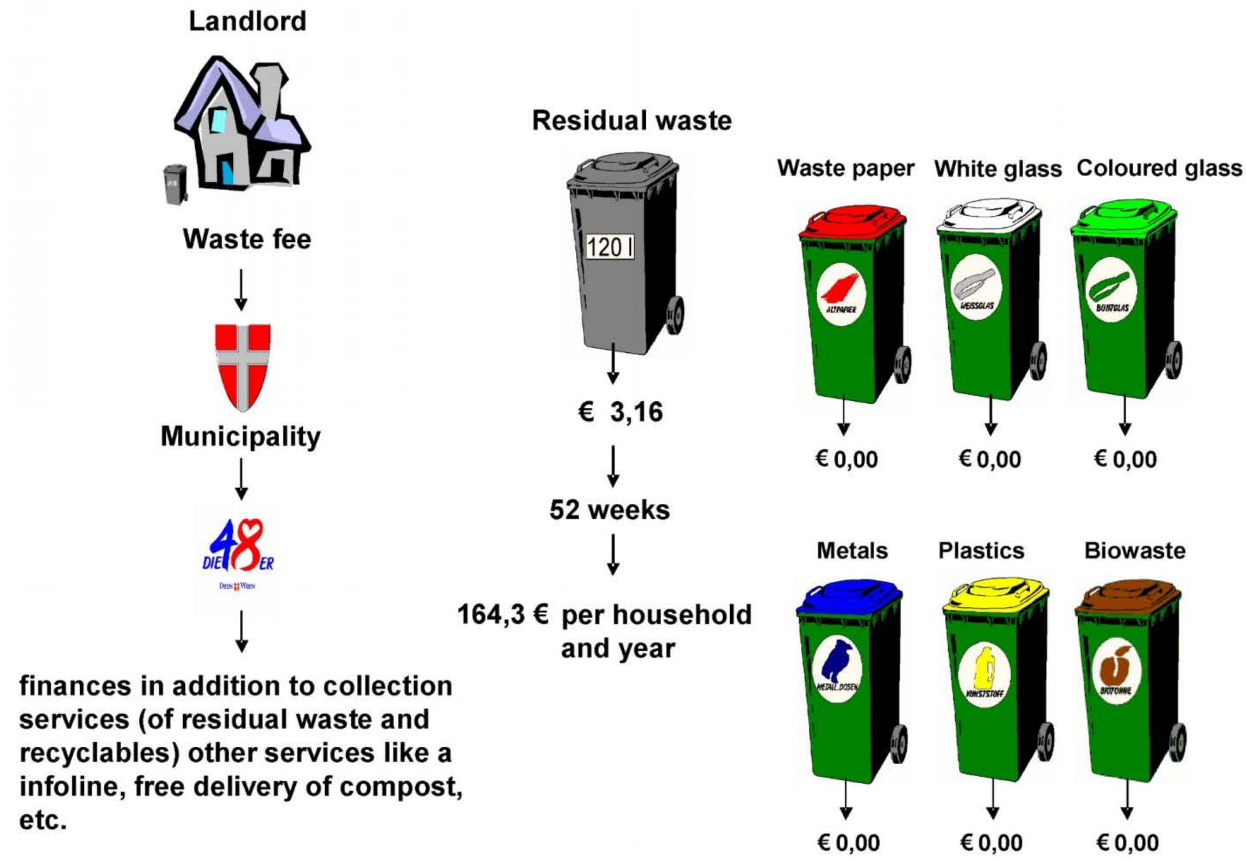


Fig. 80. Fee system for domestic waste - example Vienna

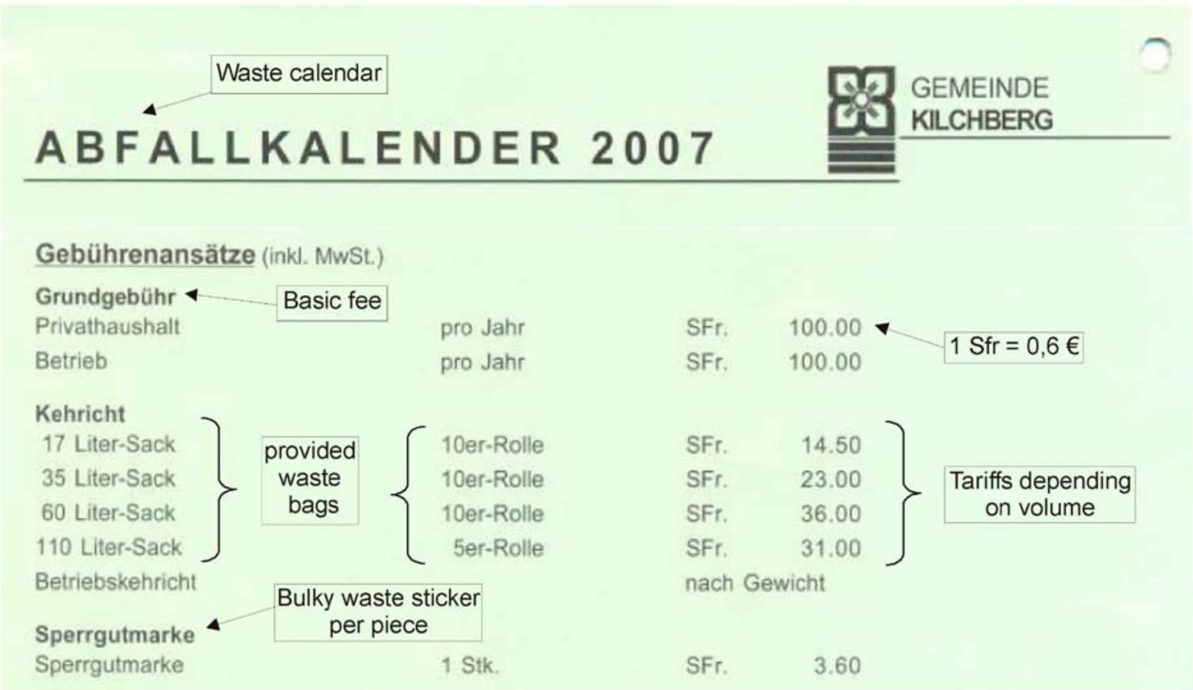


Fig. 81. Example of a pre-paid bag waste fee system of a Swiss municipality

8.4. Assessment of waste (in terms of quantity and quality)

For European member states a sound documentation of solid waste streams is required. Data reported by such documentation fulfills legal requirements on the one hand (e.g. control of targets set in the EC Landfill Directive) and provides the basis for up-to-date handling of waste streams on the other (e.g. Regional Investment Plans for Waste Management Development) - *any planning requires a sound data base in order to assess alternatives.*

Quantity & Quality Assessment of household waste represents a central tool in respect of the waste documentation system. In this chapter, some *principles* are highlighted, and *general recommendations* are presented for defining the *quantity* [12] and *quality* of waste streams (as composition, chemical-physical parameters and the like).

Such information is indispensable

- for effectively *streaming of single waste streams* (e.g. when installing systems for separate collection), and
- for *designing treatment facilities* to suit the respective feedstock properties and quantities.

8.4.1. Quantity related aspects

The exact definition of waste *quantity* is of tremendous importance and in certain respect more important than the knowledge of its *quality* (i.e. its composition by fractions, chemical elements or the like).

As an introduction to this chapter a well-known phenomenon is mentioned:

"A man's pair of eyes is quite a poor pair of scales."

Whenever waste *volumes* are converted into *weights* (i.e. in the absence of a weighbridge), a *density* of the assessed material must be assumed:

	Volume	*x*	*Density*	=	*Weight*
given in	l or m^3		l/kg or m^3/t		kg or t

In general *weight* is technically the much better measurable parameter compared to *volume.*

In practice, the waste *density* estimated by most people - from non-professional background - *is too high, in general by factor 2 to 3:* Typical estimates of the density of MSW range between *300 and 500 kg/m³.* This would mean that a standard waste container as shown to the left (volume 1.100 l, empty weight about 130 kg) would weigh half a tonne, or more - it is unthinkable that the two workers could carry it.

Recommendations

Estimates of waste weight made by sight generally lead to overestimated results ("A man's pair of eyes is a poor pair of scales"). Leaving such estimates to waste haulers also usually leads to wrong results (particularly if the collector's fee is based on weight).

It is therefore paramount that actual measurements of waste quantities be undertaken using calibrated weighbridges as follows.

Step 1: Total weight: Weighing the weight of waste of the whole community for a continuous two weeks period using an available (commercial, municipal) weighbridge, taking care to separately measure household, commercial and demolition waste.

Step 2: Defining the dwelling structures of the community with the related number of inhabitants (separate compositional analyses are carried out for each identified dwelling structure).

Step 3: Separately collecting waste from the defined, homogeneous dwelling structure areas and weighing the net weight collected over a defined time period *(e.g. one week). This enables estimate of the per capita waste generation for each dwelling structure type.*

In the absence of weighbridges at disposal facilities, these weighing campaigns must be regularly repeated over the timeframe of the waste management concept.

8.4.2. Quality related aspects

Undertaking waste quality analyses provides information on:

A) The proportion of single *material components* in waste, either according to its use as a secondary raw material - e.g. *brown glass, corrugated cardboard* - or its prior function - *glass packaging, 'Tetrapacks'*

B) The chemical properties of waste, e.g. *content of water* = moisture, content of a certain *chemical element,* particular *properties* such as the energy content measured as calorific value or salinity (e.g. for a certain feedstock used for composting) measured as electrical conductivity.

Analysis of chemical properties (B) usually follows compositional assessment (A): Once the composition *by material components* is known, the chemical-physical parameters:

> can be *measured* for individual fractions
and in a second step *calculated* by applying the mass proportions *to an overall value* for the whole waste stream

> or simply *estimated* for single fractions by using existing *databases* which have been available since the mid 1980's (e.g. calorific values, heavy metal concentrations, PCB Polychlorinated biphe- nyles or many other environmentally relevant parameters are available for *single material components).*

Fig. 82. Example of a hand sorting analysis

8.4.3. Technical standards for waste auditing

It can generally be stated that the European countries with the most experience and longest tradition in defining the composition of MSW are Germany, Austria, Switzerland and the Netherlands. In Germany sieve- based (reason for sieving is given on end of next chapter) sorting analyses as practiced today dates back to the early 1980's when the first separate collection systems (for recyclables, later on kitchen waste) were introduced on a large scale - thus requiring certain information on the future waste streams to be estimated.

In *Germany* there is still no national standard for waste auditing, however the federal states (Lander) adopt certain technical rules - more in the sense of recommendations than legal regulations - which are commonly applied. Since 2006 *Austria* has a national standard which puts strong emphasis on the principle of stratification[9], but many federal states seem likely to continue to apply their "traditional" auditing methods in order to compare results to earlier campaigns (in Austria usually performed all 2 - 5 years).

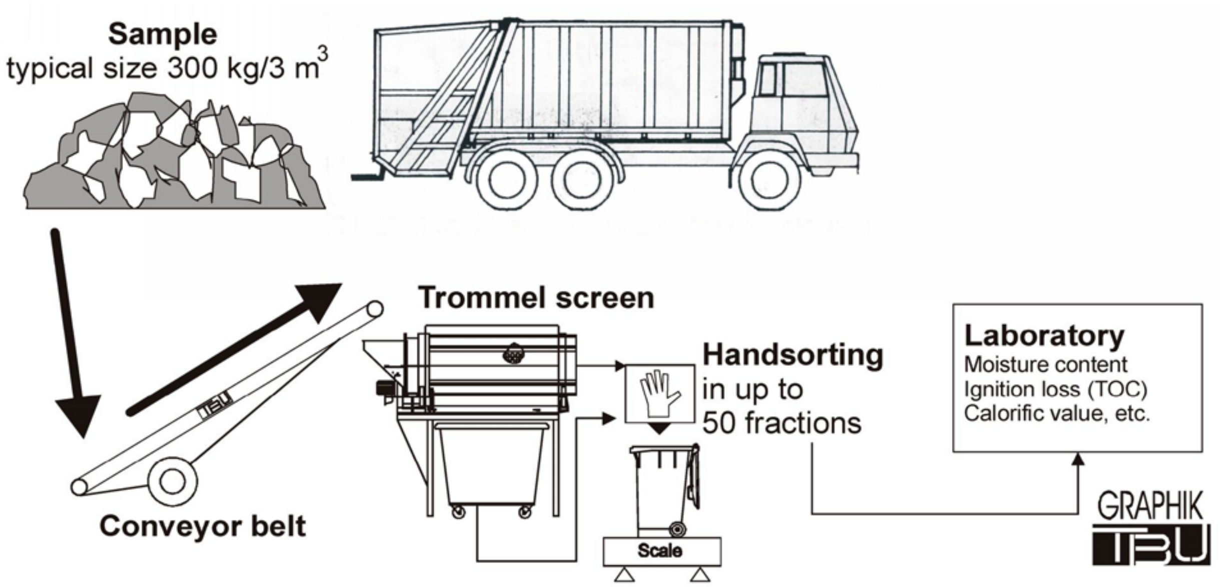


Fig. 83. Example of a mobile waste audit unit

In *Italy* a national standard (CTI-UNI 9246) is widely applied, but a quite academic regulation for preparing samples has led to practical problems.

Other countries maintain various standards / recommendations at a national and / or provincial level. Interestingly, there is still no regulation at an *EU level:* After much debate between institutes contributing to a working group a draft was recently issued. The technical applicability of the procedures outlined in this draft have however yet to be proven.

8.4.4. Sampling aspects

Sample size: To achieve a reasonable statistical validity the weight of a sample should be in the range of 1/100 to 1/1000 (as a minimum) of the socio-economic structure ('strata') which is being assessed.

Example: In a Municipality the dwelling structure "high rise buildings" is to be described, comprising 20.000 citizens with an assumed MSW generation of 260 kg/cap, yr. On a weekly basis this dwelling structure therefore generates 20.000 x 260 / 52 = 100.000 kg/wk (= 100 t/wk) MSW. A sample - taken from weekly collections - comprising 1 % of the matter to be described would be 1.000 kg (the upper range / safe side), while a sample comprising 1 % would be 100 kg (the minimum).

[9] which is not necessarily related to *socio-economic structures* only, a strata can also be defined by various *collection devices, seasons…*

The order of 400 - 800 kg of waste can be analysed by a team of say 5 workers per day (depending more on the number of samples than of sorting fractions; pre- screening - see below - as a condition).

Samples can be taken

- either *directly at source* (from collection devices i.e. garbage bins / containers), or
- *following collection,* from the waste load delivered by the collection vehicle.

Sample preparation: Pre-screening (60 ... 40 ... 20 mm) is not requested by formal regulations generally, but strongly recommended: In a screen small items can be separated from large items (in trommel screens more effectively than in vibrating screens or a simple perforated sorting table), thus the specific sorting capacity by person (doing the manual separation by components) can be multiplied by 4 to 7.

9. Chapter 9. WASTE MANAGEMENT IMPLEMENTATION: HEALTHCARE AND HAZARDOUS WASTE CONCEPT

9.1. Healthcare waste concepts

Healthcare waste (medical waste)

During recent years environment protection measures have increasingly been initiated in the healthcare sector. They require that hospitals contribute to the environmental protection through correct management of healthcare wastes. Healthcare waste should be avoided as far as possible and the generated waste must be decontaminated in an environmentally appropriate way.

Approximately 90% of the waste originating from hospitals is similar in nature to domestic waste. The remaining waste is specific to hospitals, for example infectious waste, syringes, blood, laboratory material, body and organ parts. Such waste requires specific handling in order to comply with hygiene, judicial (influenced by culture) and safety requirements.

Environmental protection requirements are found in regional, national as well as European law. Beside the regulations of waste, water, air pollution control, infection protection, industrial safety, chemicals and dangerous goods, which form the basis for a proper disposal, national judicial regulations regarding delivery and transfer must to be followed.

To separate and dispose of healthcare waste the following basic requirements must be followed:

- separate collection at the place of origin,
- correct classification of the waste to the waste key numbers,
- secure disposal in suitable bundles, as well as
- proper in-plant transport and temporary storage.

A basis for the classifying hospital waste is the *four risk groups* introduced by the World Health Organization with regard to the infection danger as follows:

1. *None* or only very low *danger.*
2. *Moderate individual danger,* low danger for the general public, effective treatment and prevention is possible.
3. *High individual dangers, low danger for the general public,* danger of serious illnesses, effective treatment and prevention possibly.
4. *High dangers for individual and general public,* high threat of severe infections, prevention and treatment normally not available.

This classification is necessary for the introduction of preventive measures in medical waste management for employees and transport.

Medical waste - waste definition

Medical waste - liquid fraction (EWC Code 18 01 02 / ASN 97103): This fraction contains one-way medical products filled with bodily fluids (blood, urine, liquor) in varying amounts (several millilitres up to litres). Since spilling must be avoided special conditions for collection and transportation apply. Leak-proof packaging is necessary for collection and transport.

Fig. 84. One-way medical products filled with body liquids

Medical waste - sharp fraction (EWC Code 18 01 01 / ASN 97105): This fraction contains all sharp objects such as syringes, scalpels, needles. Since there is a high risk of cut injuries, special conditions for collection apply. Sting- and leak- proof packaging is necessary for collection and transport.

Fig. 85. Needle with special collection container

- Infectious waste (EWC Code 18 01 03* / ASN 97101): This fraction is classified hazardous and contains all objects contaminated with bacteria of the diseases listed below. Special conditions for collection, transport and inactivation (incineration / disinfection) apply.
- Laboratory waste (EWC Code 18 01 06* / ASN 56305) is always hazardous waste. Different solvents (e.g. organic-halogen free, organic-halogenated, inorganic acids, inorganic bases) must be collected separately in order to prevent chemical reaction.
- Drugs (EWC Code 18 01 09* / ASN 53501) are hazardous waste.
- Cytotoxic drugs (EWC Code 18 01 08* / ASN 53510) are hazardous waste. Special care must be observed during collection in order to prevent endangering personal.
- Photochemistry: fixative (EWC Code 09 01 04* / ASN 52707), developer (EWC Code 09 01 01* / ASN 52723) are hazardous waste and have to be collected separately.

Principles of waste disposal in hospitals

Proper management of medical waste comprises collection, packaging, storage, transport, treatment, recycling and disposal within the medical institution (station, ambulance, laboratory) up to the final disposal (recycling, thermal treatment, landfill).

Depending on the risks (e.g. pollutants, bacteria, sharps) different requirements are established for correct disposal. Waste requiring special supervision (dangerous waste) requires a proofing procedure (i.e. disposal proof and release note / collective disposal proof and takeover sheet).

The collection of health care waste occurs in different ways as shown below:

Fig. 86. Waste collection in a hospital department

An optimized waste management concept takes into account medical, hygiene and safety factors. In order to meet these requirements different types of packaging / containers must be used. These comprise:

- One-way containers (e.g. plastic bags, plastic containers, bundles) are required for wastes bearing risks of infection or injury. Costs for acquisition and disposal of the containers must be considered.
- Multiple-use containers (e.g. containers, barrels) can be used for all non-dangerous wastes (e.g. recyclables). A basic requirement is the need for container cleaning and disinfection. This may lead to higher personnel costs.

Costs and quantities of healthcare waste

In 2002 about 90,000 tonnes of waste were produced in Austrian hospitals. 40,000 tonnes of recyclables and biogenic waste or 1.59 kg per bed and day, 44,000 tonnes non-dangerous waste or 1.87 kg per bed and day as well as about 5,200 tonnes of dangerous waste or 0.22 kg per bed and day. In addition, about 9 tons of radioactive waste resulted. (Data of the Federal Ministry of Health and Women out of 2003/2004).

Approximately 30% of the wastes from this hospital is recoverable, with the remainder comprising garbage and medical waste.

Waste produced in Austrian hospitals in 2002 (total 90.000 t)		
40.000 t	Recyclables and biogenic waste	1,59 kg per bed and day
44.000 t	Non-dangerous waste	1,87 kg per bed and day
5.200 t	Dangerous waste	0,22 kg per bed and day
9 t	Radioactive waste	—

Table 23: Waste produced in Austrian hospitals in 2002

The following charts provide information on hospital wastes for a large hospital in Austria:

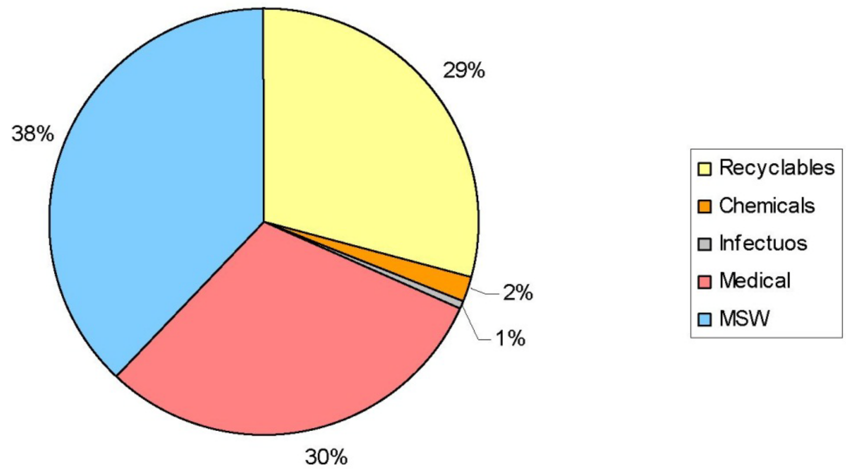


Fig. 87. Waste composition of a large hospital (Austria)

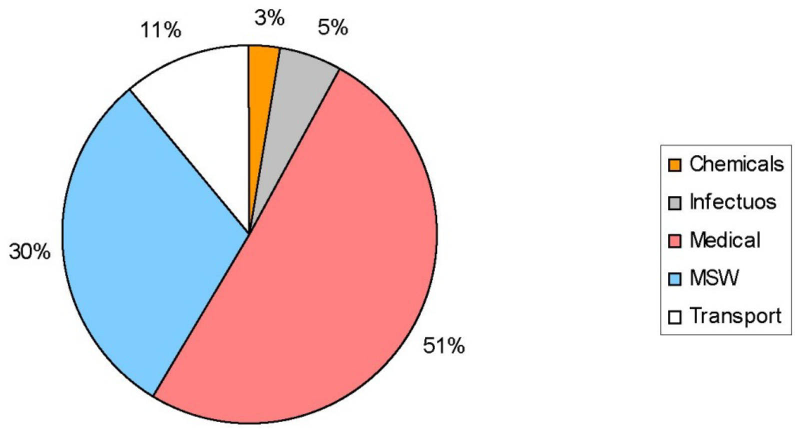


Fig. 88. Waste disposal cost per fraction a large hospital (Austria)

Half of the costs are attributable to management of medical waste. By selling recyclables approximately 1 to 2% of the disposal costs can be recovered.

Hygiene aspects of hospital waste

Hospital waste is generally regarded as infectious and it is therefore assumed that it needs to be treated as hazardous waste. In fact, only a small proportion of hospital waste is infectious. Studies have shown that MSW-like waste from hospitals contains fewer microorganisms than waste from households. Through careful management the amount of infectious waste can be minimized (and thus costs reduced). The degree of infectiousness depends on the dissemination of pathogenic bacteria. This is influenced by:

- Contagion of the pathogen
- Survival rate
- Transmission pathway
- Amount of bacteria and degree of contamination
- Amount of contaminated waste
- Severity and treatability of the disease.

Transmission by close contact with hurt or blessed skin or mucous membrane	- HIV (blood) - Viral hepatitis (blood) - TSE (transmissible spongiforme encephalopathie (tissue, liquor) - CJD, vCJD (Creutzfeldt-Jakob-Disease) - contaminated waste must always be incinerated!
Faecal-oral transmission (smear infection)	- Cholera - Dysentery - Typhoid fever
Air-borne transmission	- Plague - Pox, small pox - Poliomyelitis - Glanders - Rabies - Ularemia - Hemorrhagic fever

Table 24: Diseases which might produce infectious waste and transmission pathways (M. Scherer (2006)[15]

Based upon existing knowledge, diseases can be identified which produce infectious waste. Lists are summarized in national norms[10]. Viral hepatitis and HIV-contami- nated waste is regarded as non-infectious, even if waste is filled with liquids (e.g. blood samples). Microbiological cultures - if not autoclaved - are always infectious waste.

Infectious waste is categorized as hazardous waste[11]and must be treated thermally in specially approved waste treatment plants. Waste collection is done at the place of origin (e.g. in the station or laboratory) using one-way containers which are brought to incineration. For safety reasons it is recommended that waste be pre-packed in sealed plastic bags. Containers should be stored in a cool place to avoid gas emergence prior to collection. If waste is disinfected in the hospital it is no longer infectious and thus can be discarded together with non-infectious waste (MSW).

Safety in hospitals

Women represent nearly 80% of the health care workforce. Health care workers face a wide range of hazards, including needle stick injuries, back injuries, latex allergy, violence, and stress. Although it is possible to prevent or reduce exposure to these hazards, health care workers are currently experiencing increasing numbers of occupational injuries and illnesses.[12], including

- Blood borne infectious diseases
- HIV/AIDS, Hepatitis B Virus, and Hepatitis C Virus

[10] A: Onorm S 2104. Abfallentsorgung im medizinischen Bereich (2005) D: LAGA-Richtlinie. Richtlinie uber die ordnungsgemafte Entsorgung von Abfallen aus Einrichtungen des Gesundheitsdienstes (2002)
[11] EU: EWC Code 18 01 03 and many respective national regulations
[12] http://www.cdc.gov/niosh/topics/healthcare/

Exposure to blood and other bodily fluids occur across a wide variety of health care occupations. Workers can be exposed to blood through needle stick and other sharps injuries, mucous membranes, and skin exposures. The pathogens of primary concern are the human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV). Workers and employers are urged to take advantage of available engineering controls and work practices to prevent exposure to blood and other body fluids.

In the EU about one million employees are injured annually from the handling of needles, particularly in the health care sector. A needle stick injury occurs when the skin is pricked unintentionally. Such injuries can have serious consequences (e.g. infections with HIV or hepatitis). However, a capture problem of needle sting injuries originates from the high number of unreported cases, since reporting behaviour is poor. Hence, measures must be introduced to minimize risk. Employees should receive clear instructions and information about the correct procedures for the handling and disposal of injury-endangering objects. 47 % of the accidents in Austrian hospitals are due to injuries with sharp objects.

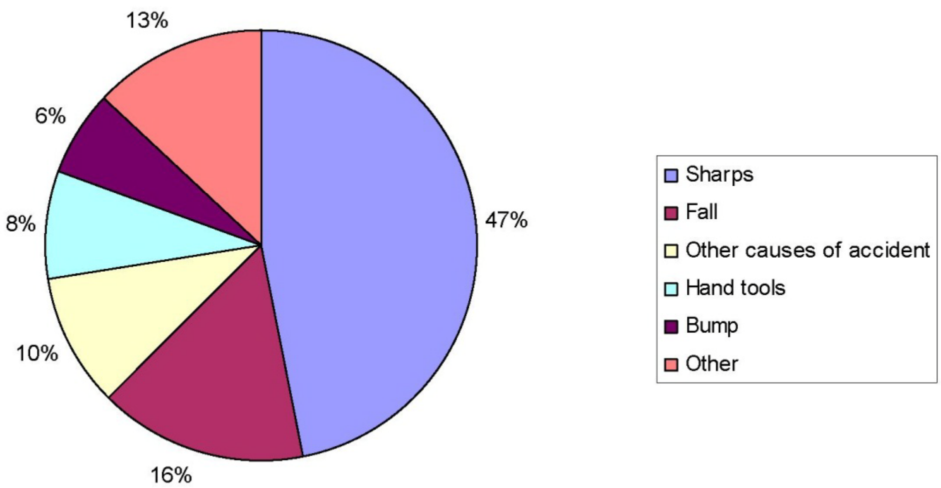


Fig. 89. Causes of accidents in Austrian hospitals

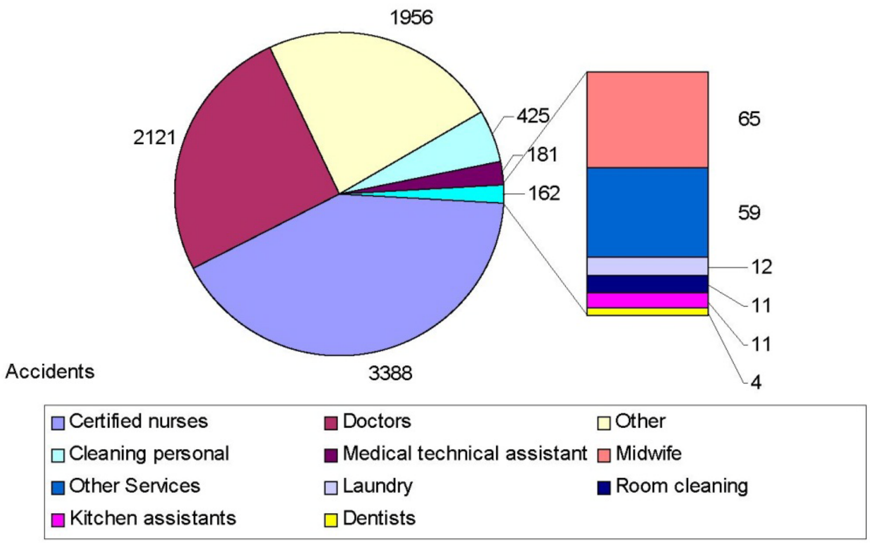


Fig. 90. Number of accidents in Austrian hospitals (2002 - 2006), sorted by professions

9.2. Hazardous Waste

Due to their chemical composition, hazardous wastes have the potential to cause significant harm to humans and the environment. The spectrum of effects is extremely widespread, thus it is very complex to establish a directive for their management.

9.2.1. Which kinds of waste are hazardous?

The Waste Catalogue Ordinance 2000/532/EC contains the entire list of waste types, covering both hazardous and non-hazardous waste. It comprises 839 waste types, of which 405 are classified as hazardous. These are marked with an asterisk (*) and represent waste requiring particular monitoring, since at least one of the hazardous properties referred to in Directive 91/689/EEC on hazardous waste is present.

9.2.2. Hazardous properties and categories of danger

The Directive on hazardous waste defines the hazardous properties on which classification of waste as hazardous is based. It is assumed that this waste exhibits one or more of the properties in Annex III to the Directive. Decision 2000/532/EC also uses the non-defined hazardous properties as a basis for classifying waste as hazardous. These properties must be taken into consideration without exception when classifying waste.

Property	Designation	Notes
H1	**explosive**	Substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene;
H2	**oxidising**	substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances
H3-A	**highly flammable**	- liquid substances and preparations having a flash point below 21 (including extremely flammable liquids), or - substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or - solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or - gaseous substances and preparations which are flammable in air at normal pressure, or - substances and preparations which, in contact with water or damp air, evolve highly flammable gases in dangerous quantities;
H3-B	**flammable**	liquid substances and preparations having a flash point equal to or greater than 21 °C & less than or equal to 55
H4	**irritant**	non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation;
H5	**harmful**	substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks;
H6	**toxic**	substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involve serious, acute or chronic health risks and even death
H7	**carcinogenic**	substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence
H8	**corrosive**	substances and preparations which may destroy living tissue on contact
H9	**infectious**	substances containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms

H10	**teratogenic**	substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce nonhereditary congenital malformations or increase their incidence

Table 24: Hazardous properties of waste in accordance with the Directive on hazardous waste

9.2.3. Handling Hazardous Waste

When a waste is classified as hazardous - and in most cases such wastes are not purely hazardous material, but contain hazardous contaminants in otherwise "harmless" waste - it needs special monitoring during collection, transport and disposal. During disposal, the treatment measures must consider both waste consistency and characteristics. For example *special incineration* must be provided for flammable wastes, e.g. pesticides and oils, which must also be burned to destroy halogenated organic compounds. Other non-flammable liquids, such as acids or galvanic residues, must be neutralized and separated through special *chemical* treatment. A third main category is solid substances which are soluble in water and thereby provide a high risk of contamination of ground water e.g. any kind of salts or dusts from flue gas treatment. The established disposal pathway for these waste is *deep mine disposal,* using closed salt mines and providing a reliable casing to prevent water contact.

9.2.4. Concept of hazardous waste management

The main aim of a hazardous waste management system is to keep hazardous wastes separate from "normal" municipal wastes.

In this respect, the following two main sectors must be addressed:

- Commerce and industry
- Private households and small enterprises.

Parallel to this the *installations for proper treatment* must be provided, initiated and monitored by the local and national administration.

<u>Commerce and industry</u>

Following the EU-Regulation and the (derived) national laws and ordinances, any large enterprise must establish its own waste management plan, documenting the quantity, quality and categorization of all wastes occurring in the business. For each waste stream, orderly disposal must be demonstrated, and procedures must be monitored by the local authorities.

Thereby, a regional "profile" of the resulting hazardous waste streams can be developed, which can be used as a basis for providing a specialized collection and transport system and a specific throughput demand at treatment facilities.

Depending on the kind of industry in the relevant region, the monitoring of these industries and commerce is the most important first step to control hazardous waste, especially to detect and eliminate illegal dumping. **Local authorities must have a clear knowledge of the technical and**

chemical operations at the different production sites, in order to recognize the specific risks and coordinate the related assessments.

Private households and small enterprises

In this sector, the main task is to obtain *information* on the hazardous impacts of the main endangering materials. The main kinds of wastes upon which management system should be based are:

- batteries and (car) accumulators
- household chemicals, such as acids
- pesticides and other poisonous materials
- paints and thinners
- waste oil
- worn out refrigerators and electronic devices

The collection system concept for these wastes must be part of the regional waste management concept. Collection options include providing door-to-door collections as well as fixed, local collection sites where people can bring their wastes. Collection sites can be located within recycling centres for other wastes. An example of a fixed container to collect hazardous waste is shown in Fig.91.

Fig. 91. Fixed collection point for hazardous waste in Vienna / Austria

Public collection sites must be staffed continuously by qualified chemists, who can estimate the character of the waste and ensure proper, separate and secure storage of the different hazardous wastes.

Installations for treatment

At the commencement of hazardous waste collection programs that the treatment facilities have sometimes not yet been fully established. Depending on the local quantities of different wastes, centralized bodies or certified enterprises will establish the required treatment capacities. Compared to treatment facilities for municipal waste, the number of specialized facilities for hazardous waste is smaller, treating waste sourced from over a far larger area. Such practice needs agreement and related contracts between several communities or regions to organize and finance these treatment facilities.

Prior to installation of treatment facilities, *interim storage capacities* can and should be provided to allow the collection as soon as possible. These storage capacities must follow a technical standard excluding any endangering impact on the environmental surroundings.

As in any other approach of separate collection of waste, *education and information* of the population and the enterprises plays a key role in the implementation of a hazardous waste management concept.

10. Chapter 10. HEALTH CARE WASTE

Healthcare waste is defined in HTM07-01 Safe management of healthcare waste as: **Waste from natal care, diagnosis, treatment or prevention of disease in humans or animals.** Examples include:

- infectious waste
- laboratory cultures
- anatomical waste
- sharps waste
- medicinal waste
- laboratory chemicals
- offensive / hygiene wastes from wards or other healthcare areas

This definition also covers wastes produced in non-healthcare environments such as university research and teaching laboratories.

The Centers for Disease Control (CDC), the U.S. Environmental Protection Agency (EPA), and the World Health Organization (WHO) concur that Health care wastes should be classified as infectious waste.

Health services are the second fastest growing economic sector in the U.S. and employ 12 million workers mostly women (80%). Hospitals generate large quantities (more than 2 million tons) of various waste requiring special disposal process on the environment. Most of them are dangerous (biohazardous) and must be packaged, transported and disposed of carefully and safely staff and the environment.

Health-care waste includes all the waste generated by health-care establishments, research facilities, and laboratories. In addition, it includes the waste originating from minor or scattered sources such as that produced in the course of health care undertaken in the home (dialysis, insulin injections, etc.).

Between 75% and 90% of the waste produced by health-care providers is non-risk or general healthcare waste, comparable to domestic waste. Healthcare waste comes mostly from the administrative and housekeeping functions of health-care establishments and may also include waste generated during maintenance of health-care premises. The remaining 10-25% of healthcare waste is regarded as hazardous and may create a variety of health risks.

(http://www.who.int/water_sanitation_health/medicalwaste/002to019.pdf)

The major sources of health-care waste are:

- hospitals and other health-care establishments
- laboratories and research centres
- mortuary and autopsy centres
- animal research and testing laboratories
- blood banks and collection services
- nursing homes for the elderly.

High-income countries generate on average up to 0.5 kg of hazardous waste per bed per day; while low-income countries generate on average 0.2 kg of hazardous waste per hospital bed per day. However, health-care waste is often not separated into hazardous or non-hazardous wastes in low-income countries making the real quantity of hazardous waste much higher.

http://www.who.int/mediacentre/factsheets/fs253/en/index.html

10.1. Definitions

Hospital waste: refers to all hospital waste, biological or no biological, that is discarded and not appropriate for further use. Hospitals generate a variety of different kinds of waste and refuse. Categorizing hospital waste helps staff keep hospitals clean and sanitary so that diseases and infections do not spread. Hospital waste is classified into different categories, and each type of refuse is handled with the necessary precautions. It may include wastes like sharps, bandages, soiled waste, disposables syringes, swabs, gauze with blood, anatomical waste, cultures, body fluids, human excreta, discarded medicines, chemical wastes, etc. Hospital waste can be a serious threat to human health if not managed in a scientific and discriminate manner. It has been roughly estimated that of the 4 kg of waste generated in a hospital at least 1 kg would be infected. Hospital waste contaminated by chemicals used in hospitals is considered hazardous. These chemicals include formaldehyde and phenols, which are used as disinfectants, and mercury, which is used in thermometers or equipment that measure blood pressure. Most hospitals do not have proper disposal facilities for these hazardous wastes.

Medical (clinical) waste: refers to material generated as a result of patient diagnosis, treatment, immunization of human beings or animals or in research activities in these fields or in the production or testing of biological materials. The medical waste cannot be considered general waste, produced from healthcare premises, such as hospitals, labs, clinics, medical doctor private practice offices and veterinary hospitals (http://en.wikipedia.org/wiki/Medical_waste).

10.2. Classification of health care waste

Health Care Waste is classified as a sub-category of hazardous wastes in many countries as they may contain toxic substances. Hazardous wastes could be highly toxic to humans, animals, and plants; are corrosive, highly inflammable, or explosive, react when exposed to certain things e.g. water and gases, and also shock-sensitive and genotoxic. Hazardous wastes in hospitals include old batteries, paint tins, old medicines, and medicine bottles. Direct exposure to chemicals in hazardous waste such as mercury and cyanide can be fatal (http://www.ehow.com/list_7367256_types-hospital-waste.html).

Health Care Waste can generally separate into two categories:

1. **Infectious**, including human, animal and organic waste contaminated with pathogens
2. **Non-infectious**, such as toxic chemicals, cytotoxic and radioactive, flammable and explosives

Each hospital should have a program management of infectious waste that provides:

- description of waste considered infectious,
- separation from the rest,
- packaging,
- storage,
- treatment,
- disposal
- measures for emergency situations, and
- staff training.

The Separation between Infectious and Non-Infectious Health Care Waste must take place at their source. Infectious waste must be placed in clean, usually waterproof plastic containers and must be specially marked with the international signal for bio-hazardous materials which are fluorescent red or orange in contrast with the color of the container.

PowerPoint Presentation Classification of healthcare waste http://www.slideserve.com/adamdaniel/health-care-waste-hospital-waste

Most hazardous waste are either burned or decontaminated prior to landfill. There is no epidemiological evidence that Health Care Waste is more infectious than other types of waste. There is also no evidence that Health Care Waste is causing diseases in the community.


Fig. 92. Containers for biohazardouds waste

The classification of healthcare waste can be also according to WHO (World Health Organization) in two categories:

1. **General** (85% of the Hospital waste**)**, non-hazardous to human beings, separating in bio-degradable (cotton, paper, packaging materials) and non-bio-degradable (plastic, soil, caps, lids, tops)
2. **Biomedical**, separated in pathological, infectious, sharps, pharmaceutical, chemical and radioactive (A. Prüss, E. Giroult, P. Rushbrook, WHO, Geneva 1999) (http://www.who.int/water_sanitation_health/medicalwaste/002to019.pdf).

The Classification of biomedical hazardous health care waste is following summarized (Table 25).

Waste category	Description and examples
Pathological	Human tissues or fluids e.g. body parts, blood and other body fluids, fetuses. Also glass slides containing fixed and embedded tissue, all materials used in embedding fixed tissue and containers with fixative for fixing tissue. *Note*: It is debated that the anatomical waste should better be regarded as a subcategory of infectious waste, rather than pathological, even though it may also include healthy body parts.
Infectious	Waste suspected to contain pathogens e.g. laboratory cultures, waste from surgery, isolation wards, tissues (swabs), materials, or equipment that have been in contact with infected patients, excreta etc. All materials which cannot be resterilized or reused within or brought into patient care.
Sharps	Any waste materials which could cause the person handling it a cut or puncture and have been used in animal/human patient care or treatment. Sharp waste include e.g. needles, infusion sets;, scalpels, knives, blades, broken glass etc.
Pharmaceutical	Waste containing pharmaceuticals e.g. pharmaceuticals products, drugs, and chemicals that have been returned from wards, are expired/ outdated or no longer needed, items contaminated by or containing pharmaceuticals (bottles, boxes).
Genotoxic	Waste containing substances with genotoxic properties e.g. waste containing cytostatic drugs (often used in cancer therapy), genotoxic chemicals. **Classified as carcinogenic** cytotoxic and other drugs such as azathioprine, chlorambucil, chlornaphazine, ciclosporin, cyclophosphamide, melphalan, semustine, tamoxifen, thiotepa, treosulfan.

Chemical	Waste containing solid, liquid and gaseous chemical substances e.g. laboratory reagents, photographic fixing and developing solutions in X-ray departments (the fixer usually contains 5-10% hydroquinone, 1-5% potassium hydroxide, and less than 1% silver and the developer approximately 45% glutaraldehyde), cleaning products, disinfectants (ethylene oxide for sterilization of surgical equipment and medical devices). Formaldehyde a significant source of chemical waste. It is used to clean and disinfect equipment (e.g. haemodialysis or surgical equipment), to preserve specimens, to disinfect liquid infectious waste, and in pathology and autopsy. Solvents used in pathology and histology laboratories and engineering departments (with halogenated compounds, such as methylene chloride, chloroform, trichloroethylene, and refrigerants, and non-halogenated compounds such as xylene, methanol, acetone, isopropanol, toluene, ethyl acetate, and acetonitrile). Organic chemicals include disinfecting and cleaning solutions such as phenol-based chemicals used for scrubbing floors, perchlorethylene used in workshops and laundries. Inorganic chemicals consist mainly of acids and alkalis (e.g. sulfuric, hydrochloric, nitric, and chromic acids, sodium hydroxide and ammonia solutions). They also include oxidants, such as potassium permanganate ($KMnO_4$) and potassium dichromate ($K_2Cr_2O_7$), and reducing agents, such as sodium bisulfite ($NaHSO_3$) and sodium sulfite (Na_2SO_3). Anaesthetic gases with applications in hospital operating theatres, during childbirth in maternity hospitals, in ambulances, in general hospital wards and in dentistry, for sedation, etc. (nitrous oxide, volatile halogenated hydrocarbons (such as halothane, isoflurane, and enflurane), which have largely replaced ether and chloroform. Wastes with high content of batteries, broken thermometers, blood-pressure gauges, etc, heavy metals. Pressurized containers Gas cylinders, gas cartridges, aerosol cans. **Classified as carcinogenic** chemicals: benzene.
Radioactive	Includes solid, liquid and gaseous waste that is contaminated with radionuclides generated from *in vitro* or *in vivo* analysis. The radioactive waste by health-care can be classified as follows: ❑ sealed sources; ❑ spent radionuclide generators;

	❑ low-level solid waste, e.g. absorbent paper, swabs, glassware, syringes, vials; ❑ residues from shipments of radioactive material and unwanted solutions of radionuclides for diagnostic or therapeutic use; ❑ liquid immiscible with water, such as liquid scintillation-counting residues used in radioimmunoassay, and contaminated pump oil; ❑ waste from spills and from decontamination of radioactive spills; ❑ excreta from patients treated or tested with unsealed radionuclides; ❑ low-level liquid waste, e.g. from washing apparatus; ❑ gases and exhausts from stores and fume cupboards

Table 25. Categories of health-care waste

Source:(http://www.who.int/water_sanitation_health/medicalwaste/002to019.pdf, http://www.authorstream.com/Presentation/prabhakarpradhan-1554437-hazardous-medical-waste/).

10.3. Evolution of health care waste political awareness

Waste from hospitals and/or other healthcare or similar facilities includes components from various physical, chemical and biological materials that require special handling and disposal due to potential specific risks to human health and the environment.

The Hospital Waste globally was brought onto focus 1983 with a system approach involving awareness, segregation and reduction of radioactive waste.

When in 1980, medical waste was found among other waste in several East Coast beaches in the U.S., the issue began to be addressed by the authorities. Considering the potential health hazard associated with Health Care Waste, EPA (US Environmental Protection Agency) prepared and presented in a conference in 1988 a management plan for the whole process of separation, collection, labeling, collection and incineration of healthcare waste. There was also created a record and defined the penalties implied for not complying with the provisions set. The two-year' (1989-1991) program came into effect in 5 states (New York, New Jersey, Connecticut, Rhode Island, Puerto Rico). The technological solutions were sought in relation to incinerators, the autoclaves (inside & outside), microwave units and various mechanical and chemical systems.

What was the conclusions reached by this program?

- The information collected show largest potential for disease occurrence at the source of medical waste, which implies primarily occupational rather than environmental risk. The risks to public health from exposure to Health Care Waste appear to be much smaller than presented.

- The various methods of Handling and Disposal of healthcare waste should be defined according to the type of waste. Those include steam or gas sterilization, radiation, incineration, thermal inactivation and chemical disinfection, followed by disposal in landfills. Today, over 90% of potentially infectious medical waste is incinerated.

Fig. 93: Spil of healthcare wastes

In the USA the Medical Waste Tracking Act of 1988 (MWTA) arose from the necessity to monitor the treatment of medical wastes through their creation, transportation and destruction, i.e. from "cradle-to-grave (1st health care legislation). The Congress approved the bill to amend the Solid Waste Disposal Act to require the Administrator of the EPA to promulgate regulations on the management of infections waste. According to the EPA (2008), medical waste is defined as "'any solid waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals.' This definition includes, (but is not limited to), blood-soaked bandages, culture dishes and other glassware, discarded surgical gloves instruments and needles used to give shots or draw blood (e.g., medical sharps), cultures, stocks, swabs used to inoculate cultures, removed body organs (e.g., tonsils, appendices, limbs) and discarded lancets (http://www.clemson.edu/centers-institutes/pearce/documents/samples/Environmental-energy.pdf).

The treatment proposition is the incineration/autoclaving as "a treatment technology involving destruction of waste by controlled burning at high temperatures" (EPA, 2007). The EPA approves of three types of incinerators for medical waste disposal: controlled air, excess air, and rotary kiln. Incineration gives off emissions such as carbon dioxide, water vapor, excess oxygen and nitrogen, and trace elements. Unfortunately harmful mercury and dioxin contaminants are released during incineration. As a result, the EPA has developed guidelines for industries to follow in order to keep the emissions to a minimum (EPA, 1995).

The EC (European Commission) Council resolution of 7 May 1990 imposed a duty on member states to regulate health care waste management. According to the EU (European Union), healthcare waste is considered to be a priority waste flow given its variability and complex composition, and in particular the potential hazard they present to human health and the environment. In 1994 the EC recommended that all member states prepare guidelines for the management of specific waste from healthcare facilities, which would define:

- Basic terminology for healthcare waste management, including definitions and classification,
- rules for health and environmental protection at the waste-generating locations,
- rules for health and environmental protection in the entire waste flow, starting from waste generation to waste disposal.

The EU legislation concerning the healthcare waste includes many Directives from 1993 to 2007 (table 26).

Short name:	**Medical devices**
Base:	Council Directive 93/42/EEC of 14 June 1993 concerning medical devices OJ L 169 of 12 July 1993
Modification:	o Directive 93/68/EEC [CE Marking] o Directive 98/79/EC of the European Parliament and of the Council of 27 October 1998 on in vitro diagnostic medical devices o Directive 2000/70/EC of the European Parliament and of the Council of 16 November 2000 amending Council Directive 93/42/EEC as regards medical devices incorporating stable derivates of human blood or human plasma o Directive 2001/104/EC of the European Parliament and of the Council of 7 December 2001 amending Council Directive 93/42/EEC concerning medical devices o Directive 2007/47/EC of the European Parliament and of the Council of 5 September 2007 amending Council Directive 90/385/EEC on the approximation of the laws of the Member States relating to active implantable medical devices, Council Directive 93/42/EEC concerning medical devices and Directive 98/8/EC concerning the placing of biocidal products on the market
Directive repealed:	76/764/EEC (repealed as from 1 January 1995)
Guide for application:	▪ Guidance on CE marking for professionals ▪ Guidelines related to medical devices directives

Table 26. EC Council Directives

Source: http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/medical-devices/index_en.htm

10.4. Health care waste generation

Very useful for *preliminary* planning of waste management is the knowledge of the healthcare waste composition which is largely as following:

- 80% general health-care waste, which may be dealt with by the normal domestic and urban waste management system;
- 15% pathological and infectious waste;
- 1% sharps waste;
- 3% chemical or pharmaceutical waste;
- less than 1% special waste, such as radioactive or cytostatic waste, pressurized containers or broken thermometers and used batteries.

http://www.slideserve.com/dava/bio-medical-waste-management-issues-and-challenges

Fig. 94: Collection of healthcare waste

Waste generation depends on the established waste management methods, the type of health-care establishment, hospital specializations, the proportion of reusable objects, and the number of the day-care patients. The generation of health-care waste differs from country to country. In middle- and low-income countries, health-care waste generation is usually lower than in high-income countries. However, the range of values for countries of similar income level is probably as wide in high income countries as in less wealthy countries. The amount of radioactive health-care waste is generally extremely small (http://www.who.int/water_sanitation_health/medicalwaste/002to019.pdf).

Several surveys have provided an indication of typical health-care waste generation (Tables 27-30).

National income level	Annual waste generation (kg/head of population)
High-income countries	
all health-care waste	1.1–12.0
hazardous health-care waste	0.4–5.5
Middle-income countries	
all health-care waste	0.8–6.0
hazardous health-care waste	0.3–0.4
Low-income countries	
all health-care waste	0.5–3.0

Table 27. Health-care waste generation according to national income level*

*Sources: Commission of the European Union (1995), Halbwachs (1994), Durand (1995).

Source	Daily waste generation (kg/bed)
University hospital	4.1–8.7
General hospital	2.1–4.2
District hospital	0.5-1.8
Primary health-care centre	0.05–0.2

Table 28. Health-care waste generation according to source size*

*Sources: Economopoulos (1993)

Region	Daily waste generation (kg/bed)
North America	7-10
Latin America	3
Eastern Asia:	
High-income countries	2.5-4
Middle-income countries	1.8-2.2
Eastern Europe	1.4–2
Western Europe	3-6

Table 29. Health-care waste generation by region*

*Sources: Durand (personal communication, 1995), Johannessen (1997).

Waste class	Daily waste generation (kg/bed)
Chemical & Pharmaceutical waste	0.5
Sharps	0.04
Combustible packaging	0.5

Table 30. Hospital waste generation by waste type in western Europe*

*Sources: Durand (personal communication, 1995), Further information may be obtained from International Healthcare Waste Network, 12–14 avenue Paul Vaillant Couturier, 94804 Villejuif, France.

Before further planning is undertaken, health-care establishments should make estimates of their own waste production, particularly for hazardous health-care wastes. Typical figures for small producers of health-care wastes in Europe are given in Table 31.

Source type	Waste generation (kg/year)
General practitioners	
▪ sharps	4
▪ infectious waste	20
▪ total waste	100
Phlebotomists	
▪ infectious waste	175
Gynecologists	
▪ infectious waste	350
Nurses	
▪ sharps	20
▪ infectious waste	100
Dentists	
▪ sharps	11
▪ infectious waste	50
▪ heavy metals (+mercury)	2.5
▪ total waste	260
Biomedical laboratories (60 analyses per day):	
▪ infectious waste	at least 300
Kidney dialysis (3 per week)	
▪ infectious waste	400

Table 31. Health care waste generation for small waste generators (Europe)*

Sources: Durand (personal communication, 1995), Further information may be obtained from International Healthcare Waste Network, 12–14 avenue Paul Vaillant Couturier, 94804 Villejuif, France.
biomedical waste treatment: http://www.youtube.com/watch?v=gj8T3yuOxEw
Medical waste sharp disposal : http://www.youtube.com/watch?v=3X8aeZkGMQQ

11. Chapter 11. HEALTH IMPACT OF HEALTHCARE WASTE

Modernization and progress has had its share of disadvantages and one of the main aspects of concern is the pollution it is causing to the earth – be it land, air, and water. With increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. This waste is ultimately thrown into municipal waste collection centres from where it is collected by the area municipalities to be further thrown into the landfills and dumps. However, either due to resource crunch or inefficient infrastructure, not all of this waste gets collected and transported to the final dump sites. If at this stage the management and disposal is improperly done, it can cause serious impacts on health and problems to the surrounding environment.

Waste that is not properly managed, especially excreta and other liquid and solid waste from households and the community, are a serious health hazard and lead to the spread of infectious diseases. Exposed waste, usually decomposing wet waste which releases bad odors, attracts flies, rats and other organisms that can spread diseases. This leads to unhygienic conditions and thereby to a rise in the health problems. The plague outbreak in Surat is good example. Plastic waste is another cause for health risks. Thus excessive solid waste where generated should be controlled by taking certain preventive measures.

The groups at risk from the unscientific disposal of solid waste include – the population in areas where there are no proper waste disposal methods, especially the pre-school children; waste workers; and workers in facilities producing toxic and infectious material. Other high-risk groups include populations living close to a waste dump and those, whose water supply has become contaminated either due to waste dumping or leakage from landfill sites.

Uncollected solid waste also increases risk of injury, and infection. In particular, organic domestic waste poses a serious threat, since they ferment, creating conditions favourable to the survival and growth of microbial pathogens. Direct inappropriate handling of solid waste can result in various types of infectious and chronic diseases with the waste workers and the rag pickers being the most vulnerable. Exposure to hazardous waste can affect human health, children being more vulnerable to pollutants. In fact, direct exposure can lead to diseases through chemical exposure as the release of chemical waste into the environment leads to chemical poisoning. Many studies have been carried out in various parts of the world to establish a connection between health and hazardous waste.

Waste from industries can also cause serious health risks. Besides, co-disposal of industrial hazardous waste with municipal waste can expose people to chemical and radioactive hazards. Uncollected solid waste can obstruct storm water runoff, resulting in the forming of stagnant water bodies that become the breeding ground of disease. Waste dumped near a water source causes contamination of the water body or the ground water source. Direct dumping of untreated waste in rivers, seas and lakes results in the accumulation of toxic substances in the food chain through plants and animals that feed on it directly, or indirectly.

Waste treatment and disposal sites can create health hazards for the neighboring environment and communities. Improperly operated incineration plants cause air pollution and improperly managed and designed landfills attract all types of insects and rodents that spread disease. Ideally these sites should be located at a safe distance from all human settlements. Moreover, landfill sites should be well lined and walled to ensure that there is no leakage into the nearby ground water sources.

Recycling carries health risks for the operators if proper precautions are not taken. Workers dealing with waste containing chemical and metals may experience exposure to toxic compounds.

Disposal of hospital and other medical waste requires special attention since this type of waste category encompasses major health hazards. This type of waste includes waste generated from hospitals, health care centres, medical laboratories, and research centres such as discarded syringe needles, bandages, swabs, plasters, and other types of infectious waste are often disposed with the regular non-infectious waste.

11.1. Occupational exposure

Hazardous hospital waste may cause “infectious and no infectious diseases”. A number of employees are exposed to this type of waste through hospital devises, in their production (hospitals, health centers, physician offices, institutes), or in their disposal (incineration, distribution) area. The principal hazardous hospital waste categories that may lead to health risks for the employees and everyone that is exposed to them are:

- Medications (chemicals, aerolised etc.);
- Bacteria (TB, Hepatitis B and C);
- Chemicals such ethylene oxide, formaldehyde, anesthetic gases;
- Chemotherapeutic agents;
- Laser smoke.

Fig. 95: Occupational exposure along healthcare waste disposal

All individuals exposed to hazardous healthcare waste are potentially at risk, including those within healthcare establishments that generate hazardous waste, and those outside these sources who either handle such waste or are exposed to a not appropriate management.

The main groups at risk are:

- medical doctors, nurses, health-care auxiliaries, and hospital maintenance personnel;
- patients in health-care establishments or receiving home care;
- visitors to health-care establishments;
- workers in support services allied to health-care establishments, such as laundries, waste handling, and transportation and
- workers in waste disposal facilities (such as landfills or incinerators), including scavengers.

The hazards associated with scattered, small sources of health-care waste should not be overlooked. Such waste sources include home-based health care, like dialysis, and illicit drug use.

WHO estimates that in 2000 injections with contaminated syringes caused 21 million hepatitis B virus (HBV) infections, 2 million hepatitis C virus infections and 260 000 HIV infections worldwide.

Many of these infections could be avoided if the syringes had been disposed of safely. The re-use of disposable syringes and needles is particularly common in some African, Asian and East European countries (http://www.who.int/mediacentre/factsheets/fs253/en/index.html).

The occupational exposure is very important while organizational factors subsidize the appearance of illness or the consequence of accidents. Table 33 shows sharps injury by category in USA (http://utminers.utep.edu/omal/Environmental%20biology.htm).

Professional category	Annual number of injuries from sharps (persons/year)	Annual number of HBV infections (persons/year)
Nurses	17700 to 22200	56 to 96
Laboratory workers	800 to 7500	2 to15
Hospital housekeepers	11700 to 45300	13 to 91
Hospital technicians	12200	24

Table 32. Occupational HBV infections through injuries from sharps (USA), WHO 1998

The routes of an infection can be:

- by ingestion / swallowing of materials (drinking and eating in non-controlled hospital areas);
- by inhalation of airborne chemicals and pathogens through the mucous membranes;
- by dermal absorption or through cuts in the skin (a.o. with water soluble toxic chemicals, that can be absorbed throughout the body);

A report by the US Environmental Protection Agency to Congress on medical waste estimated the annual numbers of viral hepatitis B (HBV) infections resulting from injuries from sharps among medical personnel and waste-management workers (Table 33).

Professional category	Annual number	Annual number of injured HBV people by sharps (injury)
Nurses		
in hospital	17700–22200	56–96
outside hospital	28000–48000	26–45
Hospital laboratory workers	800–7500	2–15
Hospital technicians	12200	24
Physicians and dentists in hospital	100–400	<1
Physicians outside hospital	500–1700	1–3
Dentists outside hospital	100–300	<1
Dental assistants outside hospital	2600–3900	5–8
Emergency medical personnel (outside hospital)	12000	24
Waste workers (outside hospital)	500–7300	1–15

Table 33. Hepatitis B infections caused by occupational injuries from sharps (USA)

Some examples of infections by exposure to healthcare waste are listed in Table 34, with the usual vehicle of transmission body fluids.

Type of infection	Examples of causative organisms	Transmission vehicles
Gastroenteric infections	*Enterobacteria, e.g. Salmonella, Shigella spp*	Faeces and/or vomit
Respiratory infections	*Mycobacterium tuberculosis Streptococcus pneumoniae*	Inhaled secretions; saliva
Ocular infection	*Herpesvirus*	Eye secretions
Genital infections	*Neisseria gonorrhoeae; herpesvirus*	Genital secretions
Skin infections	*Streptococcus spp.*	Pus
Anthrax	*Bacillus anthracis*	Skin secretions
Meningitis	*Neisseria meningitidis*	Cerebrospinal fluid
Acquired immunodeficiency syndrome (AIDS)	*Human immunodeficiency virus (HIV)*	Blood, sexual secretions
Septicaemia	*Staphylococcus spp*	Blood
Bacteraemia	*Staphylococcus spp.; Staphylococcus aureus; Enterobacter, Enterococcus, Klebsiella, Streptococcus spp.*	Blood
Candidaemia	*Candida albicans*	Blood
Viral hepatitis A	*Hepatitis A virus*	Faeces
Viral hepatitis B and C	*Hepatitis B and C viruses*	Blood and body fluids

Table 34. Examples of infections caused by exposure to health-care wastes

Chemicals and pharmaceuticals substances are commonly present in health-care waste in small proportion. Nevertheless, they may cause intoxication, either by acute or by chronic exposure, and injuries, including burns. Intoxication can result from absorption of a chemical or pharmaceutical through the skin or the mucous membranes, or from inhalation or ingestion. Injuries to the skin, the eyes, or the mucous membranes of the airways can be caused by contact with flammable, corrosive, or reactive chemicals (e.g. formaldehyde and other volatile substances). The most common injuries are burns.

Disinfectants are also important members of this group because they are used in large quantities and they may form highly toxic secondary compounds.

Chemical residues discharged into the sewerage system may have adverse effects on the operation of biological sewage treatment plants or toxic effects on the natural ecosystems of receiving waters.

Similar problems may be caused by pharmaceutical residues, which may include antibiotics and other drugs, heavy metals such as mercury, phenols, and derivatives, and disinfectants and antiseptics.

The severity of the hazards for health-care professionals responsible for the handling or disposal of genotoxic waste is governed by a combination of the substance toxicity itself and the extent and duration of exposure. Exposure to radioactive substances may also occur during the preparation of or treatment or through contact with the body fluids and secretions of patients undergoing chemotherapy.

For serious virus infections such as HIV/AIDS and hepatitis B and C, health-care professionals –in particular nurses- are at greatest risk of infection through injuries from contaminated needles. Other hospital employees and waste-management operators outside health-care establishments are also at significant risk, as are individuals who scavenge on waste disposal sites (although these risks are not well documented). The risk of this type of infection among patients and the public is much lower. Certain infections, however, spread through other media or caused by more resilient agents, may pose a significant risk to the general public and to hospital patients. For instance, uncontrolled discharges of sewage from field hospitals treating cholera patients have been strongly implicated in cholera epidemics in some Latin American countries.

11.1.1. Occupational protection

The production, segregation, transportation, treatment, and disposal of health-care waste involve the handling of potentially hazardous material.

Protection against personal injury is therefore essential for all employees who are at risk. The individuals responsible for management of health-care waste should ensure that all risks are identified and that suitable protection from those risks is provided. A risk assessment of all activities involved in health-care waste management, carried out during preparation of the waste management plan, allows the identification of necessary protection measures. These measures should be designed to prevent exposure to hazardous materials or other risks, or at least to keep exposure within safe limits.

The type of protective clothing that should be available to all personnel who collect or handle health-care waste is listed below:

- Helmets;
- Face masks;
- Eye protectors;
- Overalls;
- Leg protectors;
- Disposable gloves (medical staff) or heavy-duty gloves (waste workers).

Basic personal hygiene is important for reducing the risks from handling health-care waste, and convenient washing facilities (with warm water and soap) should be available for personnel involved in the task. This is of particular importance at storage and incineration facilities.

Viral hepatitis B infections have been reported among health-care personnel and waste handlers, and immunization against the disease is therefore recommended. Tetanus immunization is also recommended for all personnel handling waste.

Following practices contribute to a reduction in risk for personnel who handle health-care waste:

Waste segregation: careful separation of different types of waste.

Appropriate packaging: prevents spillage of waste and protects employees from waste contact.

Waste identification: recognition of the class of waste and of its source.

Appropriate waste storage: limits the access to authorized individuals only.

Appropriate transportation: reduces risks of professionals being exposed to waste.

For clearing up spillages of body fluids or other potentially hazardous substances, eye protectors and masks should be worn, in addition to gloves and overalls. Respirators (gas masks) are also needed if an activity is particularly dangerous, for example if it involves toxic dusts, the clearance of incinerator residues, or the cleaning of contaminated equipment.

A program of response should be established that describes the actions to be taken in the event of injury or exposure to a hazardous substance. All staff who handles health-care waste should be trained to deal with injuries and exposures. The program should include elements, such immediate first-aid measures, immediate reporting of the incident, retention of the item involved in the incident, additional medical attention in an accident and emergency or occupational health department, medical surveillance, blood tests, recording of the incident, investigation of the incident, and identification and implementation of remedial action to prevent similar incidents in the future.

The following key measures are essential to ensure safe use of cytotoxic drugs in minimizing exposure:

- written procedures that specify safe working methods for each process;
- data sheets to provide information on potential hazards;
- established procedure for emergency response in case of spillage or other occupational accident;
- appropriate education and training for all personnel involved in the handling of cytotoxic drugs.

In hospitals that do use cytotoxic products, specific guidelines on their safe handling should be established for the protection of personnel. These guidelines should include rules on the following waste handling procedures:

1. separate collection of waste in leak-proof bags or containers, and labeling for identification;
2. return of outdated drugs to suppliers;
3. safe storage separately from other health-care waste provisions;
4. provisions for the treatment of infectious waste contaminated with cytotoxic products.

11.2. Public health exposure

The limited ability of pathogenic microorganisms to survive in the environment is a function of its resistance to environmental conditions such as temperature, humidity, ultraviolet irradiation, availability of organic substrate material, presence of predators, etc.

The hepatitis B virus is very persistent in dry air and can survive for several weeks on a surface; it is also resistant to brief exposure to boiling water. It can survive exposure to some antiseptics and to 70% ethanol and remains viable for up to 10 hours at a temperature of 60°C. The Japanese Association for Research on Medical Waste found that an infective dose of hepatitis B or C virus can survive for up to a week in a blood droplet trapped inside a hypodermic needle. By contrast, HIV is much less resistant. It survives for no more than 15 minutes when exposed to 70% ethanol and only 3-7 days at ambient temperature. It is inactivated at 56°C (Sodeyama T et al., 1993).

Bacteria are less resistant than viruses. Much less is known about the survival of prions and agents of degenerative neurological diseases (Creutzfeldt-Jakob disease, kuru, etc.).

With the exception of waste containing pathogenic cultures or excreta of infected patients, the microbial load of healthcare waste is generally not very high. Furthermore, health-care wastes do not seem to provide favorable media for the survival of pathogens, as they frequently contain antiseptics.

In evaluating the survival or spread of pathogenic microorganisms in the environment, the role of vectors such as rodents and insects should be considered. This applies to management of healthcare waste both within and outside health-care establishments. Vectors such as rats, flies, and cockroaches, which feed or breed on organic waste, are well known passive carriers of microbial pathogens; their populations may increase dramatically where there is mismanagement of waste.

Very few data are available on the health impacts in the environment of exposure to healthcare waste. Better assessment of both risks and effects of exposure would permit improvements in healthcare waste management and in the planning of adequate protective measures. Unfortunately, the application of epidemiology meets some methodological bias and uncertainties regarding evaluation of exposure and also health impacts. The diversity of hazardous wastes must be approached with a combination of an environmental and biological monitoring of the waste-exposed population (occupational and general) and also the assessment of exposure (duration, type, way of transmission etc.). Nevertheless, suspected cases of adverse health effects of health-care waste should be adequately documented, with precise descriptions of exposure, exposed individuals or populations, and outcome.

A review of the literature relating to the need for vaccination against infectious disease in the solid waste industry was conducted, focusing on hepatitis A, hepatitis B and tetanus. Workers in the solid waste industry may theoretically be at increased risk of acquiring infectious diseases occupationally. However, at present no studies could be found which have documented this risk.

Some epidemiological results, concerning various symptoms, diseases and accidents are listed below:

1. Skin and blood infections resulting from direct contact with waste, and from infected wounds;

2. Eye and respiratory infections resulting from exposure to infected dust, especially during landfill operations;

3. Different diseases that result from the bites of animals feeding on the waste;

4. Intestinal infections that are transmitted by flies feeding on the waste;

5. Incineration operators are at risk of chronic respiratory diseases, including cancers resulting from exposure to dust and hazardous compounds;

6. Infected wounds resulting from contact with sharp objects;

7. Poisoning and chemical burns resulting from contact with small amounts of hazardous chemical waste mixed with general waste;

8. Burns and other injuries resulting from occupational accidents at waste disposal sites or from methane gas explosion at landfill sites;

9. Health surveillance for the general health care worker includes surveillance for immunity to infectious diseases such as measles, mumps, rubella, varicella, and hepatitis B;

10. Post exposure surveillance for blood borne pathogens includes HIV, hepatitis B, and hepatitis C.

The document, Workplace Solutions: Medical Surveillance for Health Care Workers Exposed to Hazardous Drugs, supplements previous NIOSH (The National Institute for Ocupational Safety and Health) resources that highlighted potential health risks for health-care employees who are exposed to hazardous drugs.

The U.S. health care industry is one of the fastest growing sectors, with over 16.6 million workers in 2005. It is estimated that 5.5 million of these health care workers are potentially exposed to hazardous drugs or drug waste, including pharmacists, nurses, physicians, maintenance workers, operating room personnel, and others who may come into contact with these drugs while performing their job.

Hazardous drugs are those that have been determined through research studies to have a potential for causing harm to healthy individuals, including potential risks of cancer, skin rashes, birth defects, and reproductive toxicity. These same drugs also play a critical role in treatment of patients with serious illnesses like cancer and HIV infection. Although the potential therapeutic benefits of hazardous drugs outweigh the risks of side effects for ill patients, exposed health care workers risk these same side effects with no therapeutic benefit.

"*Medical surveillance programs are important in the workplace for establishing a baseline for individuals' health and monitoring their health over time*," said NIOSH Director John Howard, M.D. "*The recommendations in this document, which were developed in partnership with health care professionals, offer practical and effective measures for instituting and maintaining safe, efficient procedures for handling hazardous drugs*."

The recommendations include:

- Health questionnaires, laboratory tests, and a physical examination completed at the time the worker is hired, and updated periodically.
- Follow-up with those workers who have shown changes in their health or have had a significant exposure.

Establishing a medical surveillance program helps to detect changes in workers' health, allowing employers to evaluate the current practices and identify changes needed to help protect other workers from exposure. To view the complete report and all the recommendations made by NIOSH visit www.cdc.gov/niosh/docs/wp-solutions/2007-117/.

In the last few years there has been growing controversy over the incineration of healthcare waste. Under some circumstances, including when wastes are incinerated at low temperatures or when plastics that contain polyvinyl chloride (PVC) are incinerated, dioxins and furans and other toxic air pollutants may be produced as emissions and/or in bottom or fly ash (ash that is carried by air and exhaust gases up the incinerator stack). Exposure to dioxins and furans may lead to the impairment of the immune system, the impairment of the development of the nervous system, the endocrine system and the reproductive functions. WHO has established a Provisional Tolerable Monthly Intake for dioxins, furans, and polychlorinated biphenyls.

The unsafe disposal of healthcare waste (for example, contaminated syringes and needles) poses public health risks. Although treatment and disposal of health-care waste reduces risks, indirect health risks may occur through the release of toxic pollutants into the environment through treatment or disposal.

- Landfills can contaminate drinking-water if not properly constructed. Occupational risks exist at disposal facilities that are not well designed, run, or maintained.

- Incineration of waste has been widely practiced but inadequate incineration or the incineration of unsuitable materials results in the release of pollutants into the air and ash residue. Incinerated materials containing chlorine can generate dioxins and furans, which are human carcinogens and have been associated with a range of adverse health effects. Incineration of heavy metals or materials with high metal content (in particular lead, mercury and cadmium) can lead to the spread of toxic metals in the environment. Dioxins, furans and metals are persistent and bio-accumulate in the environment. Materials containing chlorine or metal should therefore not be incinerated. When incinerators burn unfortunately, not only infectious waste and other materials that are recyclable, such as paper and cardboard, they emit into the environment-even hundreds or thousands of kilometers away, air pollutants, such as hydrochloric acid, furans and dioxins and toxic metals, such as lead, cadmium and mercury.

Fig. 96: Incinerator for medical waste

Only modern incinerators operating at 850-1100°C and fitted with special gas-cleaning equipment are able to comply with the international emission standards for dioxins and furans. Alternatives to incineration are now available, such as autoclaving, microwaving, steam treatment integrated with internal mixing, and chemical treatment (http://www.who.int/mediacentre/factsheets/fs253/en/index.html).

Fig. 97: Health effects from incinerator emissions

Mercury can cause growth problems and mainly affects the nervous system. Exposure to particles seems to be associated with exacerbation of respiratory symptoms and cardiovascular diseases and increased risk of premature death. Hydrochloric acid from incinerators is a clear colorless gas. Chronic exposure to hydrochloric acid may cause gastritis, chronic bronchitis, dermatitis and photosensitivity. Acute human exposure to high levels of chlorine can cause chest pain, vomiting, toxic pneumonitis, pulmonary edema and sudden death. At lower levels, chlorine is possible irritant to eyes, respiratory tract and lungs. Exposure to dioxins and furans can cause dermatitis, cancer and reproductive problems such as endometriosis. Also, these pollutants affect the immune system.

It is important to note that only a small portion of medical waste is infectious, because most non-infectious waste is sent to other incinerators. Non-infectious waste especially plastics often come to incineration for example as packing. The Centers for Disease Control and Prevention (CDC) estimate that non-infectious medical wastes constitute about 85% of the total volume and only 15% are infectious (2% pathological waste and 24% other medical waste).

U.S. regulations apply since 1997 with instructions and limit values. The application of such regulations lead to a decrease of emissions down to levels 75 to 98% of those in 1997, especially in urban densely populated cities, and in several rural areas. The regulations also provide flexibility in their application to small community hospitals to assist in reducing pollutants in the environment.

Thus, EPA proposed alternative on-site disinfection using technologies such as:

- **Thermal** (low 350 º, medium 350 º -700 º and high 1000 º -> 1500 º F), electropyrolysis;
- **Chemical** (chlorine, ozone, peroxyacetic acid);
- **Radiation** (ionizing, e-beam, microwave);
- **Biological** (enzymes).

How can one really make the best choice among these alternative non-incineration technologies?

Initially, an analysis of the type and volume of hospital waste is needed. The estimated average volume of waste is 8-45 pounds/bed/day. The best choice also depends on the effectiveness of the microbiological method accepted by the regulations, environmental emissions, the planning requirements, the OHS issues, noise, odors, automation, applicability, merchantability, maintenance costs, etc (Table 36).

Type of infectious waste	Recommended treatment techniques†			
	Steam sterilization	Incineration	Thermal inactivation	Chemical disinfection§
Isolation wastes	X	X		
Cultures and stocks of infectious agents and associated biologicals	X	X	X	X
Human blood and blood products	X	X		X
Pathological wastes	X††	X		
Contaminated sharps	X	X		
Contaminated animal wastes:				
Carcases and parts	X††	X		
Bedding		X		

†*The recommended treatment techniques are those that are most appropriate and are generally in common use; an alternative treatment technique may be used to treat infectious waste if it provides effective treatment*
§*Chemical disinfection is most appropriate for liquids.*
***Discharge to the sanitary sewer for treatment in the municipal sewage system (provided that secondary treatment is available).*
††*For aesthetic reasons, steam sterilization should be followed by incineration of the treated waste or by grinding with subsequent flushing to the sewer system in accordance with State and local regulations.*
§§*Handling by a mortician (burial or cremation).*
Sterilization:http://www.youtube.com/watch?feature=endscreen&v=qtd2gNZIN-k&NR=1

Table 36. Recommended techniques for treatment of infectious wastes (*EPA, 1986*)

Not all solid waste can be incinerated. Inappropriate incinerators as well as technical infeasibility of complete combustion for certain wastes (plastic, chemical and radioactive products, mercury, heavy metals, etc.) can generate air pollution. For this reason, incinerators are recommended in the action plan as part of a waste segregation strategy at the source, in order to greatly reduce the infectious wastes and restrict the contamination of other non-contagious wastes (papers, plastics, pipes and syringes, etc.).
Incinerators: http://www.youtube.com/watch?v=3EeVYBY_iw0

Not all types of wastes should be incinerated. Selective sifting will be used to send all non-contaminated wastes towards more classical treatment systems (disinfection, burial, garbage dumps), so that only the contaminated or risk-based wastes (needles, etc.) will be incinerated. These categories of wastes do not emit toxic products (or very few), especially dioxins and mercury.

Fig. 98: Containers for medical waste disposal
Source: (www.h2e-online.org) (http://practicegreenhealth.org/0

Incineration allows total melting of needles which are the most feared vectors for the accidental transmission of HIV/AIDS. In health centres located in district and rural areas, the quantities of health care wastes produced are very small. If segregation is respected, the volume to be incinerated will be insignificant. In addition, the promotion of the use of non-chlorinated plastic containers will help reduce pollution stemming from incineration. In order for institutions to meet waste management standards, the following alternative options are proposed: chemical disinfection; safe land-filling or burial within hospital grounds (if appropriate area is available). Other systems (autoclaving, microwaves) are not recommended because they are very expensive and require highly qualified staff for their operation. For liquid wastes, chemical disinfecting is the most effective way of treating infectious wastes. A combined system would be recommended (disinfecting and septic tank) for Regional and rural health facilities. In the central hospitals, owing to the important volumes of water involved, it is preferable to choose a physico-chemical treatment, including a disinfecting post. However, this system requires more detailed study in terms of feasibility.

12. Chapter 12. HEALTHCARE WASTE MANAGEMENT

Improving healthcare waste management at the national, regional, and local level is very important. Surveys on the generation of waste are the basis for identifying opportunities -and setting targets- for waste minimization, reuse and recycling, and cost reduction. A national programme of sound healthcare waste management is achievable through an action plan. http://www.authorstream.com/Presentation/prabhakarpradhan-1554437-hazardous-medical-waste/

12.1. International recommendations for waste management

Agenda 21 (UNO document for sustainable development) recommends a set of measures for waste management. The recommendations may be summarized as follows:

- **Prevent and minimize** waste production.
- **Reuse or recycle** the waste to the extent possible.
- Treat waste by **safe and environmentally sound methods**.
- Dispose of the final residues by landfill in **confined and carefully designed sites**.

Agenda 21 also stresses that any waste producer is responsible for the treatment and final disposal of its own waste; where possible, each community should dispose of its waste within its own boundaries. The European Union has elaborated a common “European Community Strategy on Waste Management”; other regional groupings of countries may set up similar policies in the future Clinical waste management

http://www.slideserve.com/zoltan/safe-management-of-healthcare-waste

International agreement has been reached on a number of underlying principles that govern either public health or safe management of hazardous waste. The policy document should outline the rationale for the legislation, plus national goals and the key steps essential to the achievement of these goals, and may contain the following:

- descriptions of the health and safety risks resulting from mismanagement of health-care waste;
- reasons for sound and safe health-care waste management practices in health-care establishments;
- listing of approved methods of treatment and disposal for each waste category;
- warning against unsafe practices, such as disposing of hazardous health-care waste in municipal landfills;
- management responsibilities within and outside health-care establishments;
- assessment of the costs of health-care waste management;
- key steps of health-care waste management: minimization, separation, identification, handling, treatment, and final disposal of waste; technical specifications for the implementation of each step should be described in separate technical guidelines;
- record-keeping and documentation;
- training requirements;
- rules governing the protection of workers' health and safety

The technical guidelines associated with the legislation should be practical and directly applicable. They should include the following specifications, with sufficient detail to ensure that safe practices are observed and appropriate standards achieved:

- legal framework concerning safe management of health-care waste, hospital hygiene, and occupational health and safety (limits of emission of atmospheric pollutants and measures for protection of water resources may be addressed here or in the other national guidelines);
- the responsibilities of public health authorities, of the national environmental protection body, of the heads of health-care establishments, of the scattered and smaller producers of health-care waste; and of the heads of any private or public waste-disposal agencies involved;
- safe practices for waste minimization;
- separation, handling, storage, and transport of health-care waste;
- recommended treatment and disposal methods for each category of health-care waste and for waste water.

Gradual implementation of the law is recommended against attempting to introduce all measures simultaneously (UNEP, 1997).

12.2. Guidance for small healthcare facilities

This section is generally appropriate for small healthcare facilities with less than 50 beds or immunization posts, that have relatively few resources for Health care waste management (Johannessen, L., et al., 2000, HNP Discussion Paper)).

Website: www.healthcarewaste.org

It is important to commence by surveying the facility's current healthcare waste practices. Careful completion of the following checklist should identify problems and risks involved in waste management. The steps outlined in follow are basic elements of good Health care waste management and should be reviewed by managers and project teams involved in healthcare or waste management projects. If a facility cannot implement these steps on its own, it should seek help from waste management experts.

12.2.1. Small Facility Assessment Checklist

General facility information

- How many employees does the facility have?
- How many beds does the facility have, and what is the bed occupancy rate?
- What medical and supporting departments does the facility have? (pharmacy, laboratories, kitchen, general store).

Handling of healthcare waste

- How much healthcare waste is generated daily by each department or at each ward/lab within the healthcare establishment?
- How much of this is special healthcare waste? (the answer determines the magnitude of the problem and treatment method).

- What is the general composition of the waste (plastic, cotton, food waste, sweepings?) Visit all wards, specialized departments, laboratories (including blood bank), pharmacy, kitchen, and general store to note the waste composition at each location.

- How and where is the facility's healthcare waste stored before collection?

- Does any formal or informal separation of waste take place? (resale of syringes, recycling of plastic, extraction of silver if x-ray films?)

- Does the establishment generate any wastes of special concern, such as radioactive waste, cytotoxics, pathological waste, reagents, or outdated pharmaceuticals? How and in which department are each of these special wastes generated? How is their disposal handled?

- How is liquid waste handled? Specify for cytotoxics, reagents, and used x-ray film processing liquids. If the liquid waste is discharged in the sanitation system, where does the latter discharge and what is its capacity?

<u>Treatment and disposal of healthcare waste</u>

- What treatments (if any) are done to the waste before disposal? How efficient are the treatments and how are residuals handled?

- Is the healthcare waste disposed of at the healthcare facility or off-site?

- If any waste is taken off-site, how is the waste transported outside the premises of the healthcare facility? How is the waste packaged? What types of vehicles are used to transport the waste?

- Is any of the waste taken to a dump or landfill site? If so, what happens to the waste at this facility? (buried immediately after arriving, burned on the site or left unattended at any time after being unloaded?)

- If there is open access to the landfill/dump, to what extent do waste pickers, children, or others have access to the healthcare waste?

<u>Management issues</u>

- Who is responsible for healthcare waste management at the healthcare facility?

- What are the current operational standards for HCW and what are the applicable national, regional, and local policies?

- How many people are involved in waste collection and are special skills required by the healthcare facility? What sort of worker safety measures are in place?

- Is procurement of new healthcare materials reviewed to reduce the waste stream and to avoid potential treatment problems?

- What are the daily waste collection routines, including waste packaging?

- What are the transportation needs and costs?

- How much does HCW management cost the facility? Does the budget provision cover these costs?

Risks of the current waste management system

- Does the management of the healthcare facility have concerns about the facility's current HCW practices? If so, what problems do they identify?
- Does the assessment above indicate that the facility's current waste management practices pose any health risks to patients, nurses or doctors, other staff, or visitors? If yes, what kind of risks?
- Does the waste pose any risk to waste collectors? If yes, what kind?
- What are the risks for spillage of waste or for scavenging along the transportation route?
- Does the waste disposal system pose any risk to waste-pickers or users of resold/recycled waste? If yes, what kind?

12.2.2. Basic Steps in healthcare waste (HCW) Management at Small Facilities

Raise awareness at the management level and develop an integrated waste management plan
The managers need to recognize the importance of good healthcare waste management, and should designate a waste management team or working with the existing infection control committee. It is important to develop a waste management plan for the facility that is integrated into the daily operations.

Ensure segregation of special HCW from other waste generated at the establishment
Categorize the waste generated at the facility as either municipal solid waste or special healthcare waste. The first priority should be segregating sharps and pathological waste from all other waste. Sharps must be put into rigid, puncture-proof containers, which should be available at the health worker's workplace. Pathological waste should be put into non-transparent plastic heavy-duty bags. Toxic liquids and pharmaceuticals should also be separated from regular solid waste materials, and disposed of properly. From a cost- and waste-management perspective, syringes that can be re-used (after proper cleaning and sterilization in a steam sterilizer) are preferable to disposable syringes. From a public health perspective, one-time use or auto-destruct needles are safer. Evaluation of local conditions is needed to make an informed decision.

Determine the most appropriate treatment and disposal site for the facility's waste
Generally speaking, small healthcare facilities in urban areas should choose off-site treatment and disposal for both economic and safety reasons -- most often in the municipal landfill.

Landfills should be protected from human and animal waste pickers. Burial of HCW and other municipal solid waste in a municipal landfill could be done by the person who delivers the waste from the healthcare facility, or by a person employed at the landfill. In either case, this person must receive specific instructions for such burial. Nevertheless, cytotoxics and other hazardous chemical wastes should never be buried in a landfill. Instead, they need to be returned to the original supplier or incinerated at a central facility. Other special HCW should also receive more intensive treatment to ensure a reduction in public health and environmental consequences.

Small, isolated facilities with limited resources and without access to centralized waste treatment and disposal may find burial of special healthcare waste their best solution. Such burial should be done only under controlled circumstances, in a secluded area following landfill principles, including liners, water diversion, groundwater monitoring, careful sitting and gas release mechanisms.

Develop and implement a healthcare waste management plan

Every healthcare facility should have or develop a waste management plan that includes daily routines for collection, handling, segregation, and packaging of the different categories of waste.

The managers should ensure that this plan is in place, with adequate budget and personnel to implement it. Implementation of the healthcare waste management plan and routine monitoring should be carried out in parallel with the training program described below.

Train healthcare workers in proper HCW procedures

All healthcare staff should be aware of the facility's basic healthcare waste management plan and their role in the plan. This includes management and regulatory staff, medical doctors, nurses and nursing assistants, cleaners, waste handlers, and visitors to the facility. The waste management plan should be presented in simple terms and displayed in a diagram at all points of waste generation. Better health and environmental working conditions for waste handlers should be addressed in planning resources for waste management. This includes but is not limited to the use of protective clothing and specialized equipment to ensure worker safety as well as safety for the general public. Hands-on staff training in the details of the waste management plan is optimal.

12.3. Guidance for large health care facilities

The checklist and recommended steps outlined below are appropriate to guide a review of waste management operations at a larger healthcare facility (more than 50 beds). They should also be reviewed during any major upgrading of a large healthcare facility, establishment of a new healthcare facility, or as part of regional Health Care Waste management projects (Johannessen, L., et al., 2000, HNP Discussion Paper)).

The following units provide guidelines for assessing current HCW management practices within the healthcare facility and suggested steps to improve HCW management. Centralized waste treatment and disposal often make sense for large healthcare facilities, especially those in large urban areas or in smaller communities served by a central waste system.

12.3.1. Large Facility Assessment Checklist

<u>General facility information</u>

Basic data

- How many employees are there at the facility in total and within each category? (medical doctors, nurses, other healthcare professionals, waste collectors, cleaners, and other hospital staff).
- What are the facility's medical specialties and departments?

- How many beds does the facility have within each medical specialty?

- What other departments support the medical departments? (laboratories, blood bank, radiology, operating theaters, intensive-care units, renal dialysis units, and outpatient services).

- What non-medical departments are there? These may include general store, laundry, operations and maintenance, workshops, kitchen, and waste management department.

Financial data

- What is the facility's annual budget?

- How much is spent on salaries and wages; medical supplies; pharmaceuticals; maintenance and services expenses; consumables; and waste management?

Health conditions among employees

- What is the prevalence of HBV, HCV, HIV, malaria, and syphilis among the categories of employees at the healthcare facility, compared to the general public?

<u>Handling of healthcare waste</u>

Healthcare waste composition and quantity

- What is the composition of the facility's healthcare waste? Determine by segregating random portions of the waste into defined waste categories. Weigh the total portion and each segregated fraction of the waste; a hand-held scale may be used.

- What are the major sources of special healthcare waste? How much is generated by each medical and non-medical department? Is HCW segregated? What are the major sources of liquid healthcare waste, hazardous waste, and radioactive waste? Can the source be reduced?

- What is the total quantity of HCW generated at the healthcare facility? This may be determined through a 1-4 week survey in which all waste generated/disposed of at the healthcare establishment is weighed. Weighing may be done by truckload or by weighing every container/trolley immediately after collection.

- How much of this is special HCW (sharps, pathological etc.)?

- What is the amount of total healthcare waste and special healthcare waste generated per bed per day?

Healthcare waste collection

- What are the facility's healthcare waste collection practices? Include:

- Level of segregation at source of waste

- Location of collection points at department/ward level

- Storage before collection by waste collectors

- Routines for waste and laundry collection (since laundry procedures often can be applied to healthcare waste collection)
- Collection equipment (trolleys, push carts, etc.)
- Storage before final disposal or external transportation
- Special procedures for liquid wastes
- Special procedures for pharmaceuticals and cytotoxics

Treatment and Disposal

Treatment and disposal on the facility premises

- What are the on-site practices for healthcare waste treatment? (crushing of sharps, sterilization, chemical disinfection, destruction through burning or incineration).
- What are the practices for on-site disposal? (landfilling or dumping of healthcare waste or residuals from treatment, incineration).
- Is any of the healthcare waste recycled? (e.g. using kitchen waste for animal feeding, recovering silver from x-ray films, reusing cardboard from the general store).
- Does informal segregation/recycling of waste (syringes, unused medicine, etc.) take place by healthcare workers or waste collectors? If so, does this informal activity contribute to healthcare workers' income?

Treatment and disposal outside the facility's premises

- Is the facility's healthcare waste treated at a central treatment facility before final disposal?
- Is the facility's healthcare waste disposed of at a municipal dump/landfill?
- Does any scavenging of healthcare waste occur at the treatment or disposal site? If so, what waste is being scavenged and how does it contribute to waste-pickers' income?
- How significant is the scavenging in terms of the number of people involved?

HCW management and regulations

Healthcare waste management on the facility premises

- Which departments and staff members at the facility are involved in healthcare waste management?
- Who are the key people within the facility responsible for HCW issues? (manager, members of the infection control committee, and the engineering manager).
- Have any outside parties been hired to help with the facility's waste collection, treatment, transportation, or disposal? If so, what aspects of waste management are they responsible for, and who is accountable for their performance?
- Does the facility conduct any training and public awareness programs on HCW management?

- Who pays for hauling and disposal of special HCW?

The role of outside authorities

- Which authorities are involved in HCW management at the municipal/regional/ national level? These may include municipal waste management authorities for bylaws on disposal of healthcare waste; environmental authorities (local/regional) for emissions standards from treatment plants; health authorities (regional/national) for internal hygiene and infection control requirements; and occupational health authorities (local/regional) for regulations governing for healthcare workers and waste collectors.

Budget issues

- How much does HCW management cost the facility? Is the budget provision adequate for these costs?

- Who pays for hauling and disposal of healthcare waste?

Healthcare waste regulations

- What existing healthcare waste regulations govern the facility? Are they specific to the facility or set by a higher governing body?

- What regional and national regulations apply to the facility's healthcare waste situation?

Risks of the current waste management system

- Does the management of the healthcare facility have concerns about the facility's current HCW practices? If so, what problems do they identify?

- Does the assessment above indicate that the facility's current waste management system poses any health risks to patients, nurses or doctors, other staff, or visitors? If yes, what kind of risks?

- Does the waste pose any risk to waste collectors inside the hospitals? If yes, what kind?

- What are the risks for spillage of waste or scavenging along the transportation route?

- Does the disposal system pose risks to scavengers or users of resold/recycled waste? If yes, specify.

- Are there other problems involved in the handling of the facility's healthcare waste?

12.3.2. Basic Steps in HCW Management at Large Facilities

The steps outlined below are basic elements of good healthcare waste management at large facilities, listed in order of priority. These steps should be reviewed carefully by facility managers, even if completion of the checklist above does not identify problems or risks involved in waste management at the facility. If a facility cannot implement these steps on its own, it should seek help from waste management experts.

Raise awareness

Managers of the healthcare facility should raise awareness of the importance of proper HCW management and designate a group with responsibility for overseeing the HCW situation.

Ensure that special healthcare waste is segregated from other waste for disposal

Healthcare waste must always be segregated into special HCW and other waste. Waste segregation facilitates safe handling of special HCW and minimizes the amount of special waste requiring special treatment or disposal techniques. First, sharps must be separated from all other waste and stored properly in appropriate containers. If any radioactive waste is generated, international standards for disposal must be followed.

Determine appropriate treatment technology

Some decisions regarding treatment technology are made at the healthcare facility level and others are made at the national or regional level. The satisfactory destruction of special healthcare waste is a major problem facing health services today. Research and development are still needed to find inexpensive and acceptable ways of destroying special healthcare waste. Landfilling of special HCW by burial in other municipal solid waste should only be considered for small quantities of waste. For a city with larger facilities, a special landfill cell or pit should be developed to receive special HCW. If land filling is not an option, incineration, sterilization (autoclave or microwave), chemical disinfection, or a combination of these technologies need to be considered.

Consider facility-based vs. centralized waste treatment and disposal options

The choice between on-site or off-site treatment and disposal is often a political decision made at the regional or municipal level. If a healthcare facility is very large, or located near many other healthcare facilities, potential economies-of-scale should play a role in the decision. In many cases, environmentally-sound incineration sterilization, and/or landfill disposal will necessarily take place off-site. However, a large healthcare facility with adequate technical and financial capacity can consider installing an incinerator and even providing services to other nearby healthcare facilities (at cost).

Ensure proper packaging and storage of special healthcare waste

Primary packaging and storage takes place where waste is generated. Secondary packaging is used for transportation. Primary packaging of special healthcare waste should be in leak-proof and disposable bags or containers. Containers for sharps must be puncture-proof and should not be made of glass. A color code of yellow or red should be chosen for all special healthcare waste. For pathological waste, the opposite (and non-transparent) color should be used. For secondary packaging, leak-proof solid containers mounted with wheels should be used for easy transport. Color coding of secondary packaging should follow the primary packaging color code. The centrally located storage room should also be secured. In-house storage may consist of two levels:

a) A well-ventilated room at or near the ward, where waste collectors will pick up the waste; and

b) A centrally-located storage room, where temperatures can be kept low (e.g. air conditioned), until waste is picked up for treatment.

Ensure safe transportation of special healthcare waste on public roads.

If the waste treatment and/or disposal facility is located off-site, the vehicle that transports special HCW should be used exclusively for this purpose.

Determine whether or not an environmental assessment is needed

If major new waste treatment facilities are being planned, an environmental assessment study may be needed. Simple projects or the upgrading of healthcare waste management systems generally do not cause significant environmental impacts (environmental impact is needed by quantities of healthcare waste that overwhelm the existing capacity or by construction of major new waste disposal facilities).

Develop a HCW management plan for the facility

Every healthcare facility should have or develop a waste management plan that includes daily routines for collection, handling, segregation, and packaging of the different categories of waste. Facility managers should ensure that this plan is in place, with adequate budget and personnel to implement it.

Train healthcare workers in HCW management procedures

Healthcare staff should be aware of the facility's basic healthcare waste management plan and their role in the plan. This includes management and regulatory staff, medical doctors, nurses and nursing assistants, cleaners, waste handlers, and visitors to the facility. Training programs should include proper instruction on the use of protective clothing, materials, and special equipment to ensure the safety of the HCW employee and the general public.

Address scavenging issues

If scavenging has been identified as a problem, steps need to be taken to protect waste pickers and to prevent access to hazardous waste. If possible, waste-pickers should also receive assistance to move into other income-generating activities. Alternative methods of waste management might be considered in these cases, to help reduce the risk to public health.

12.4. Development plan by who

The first global and comprehensive guidance document, *Safe management of wastes from health-care activities*, originally released by WHO in 1999, addresses aspects such as regulatory framework, planning issues, waste minimization and recycling, handling, storage and transportation, treatment and disposal options, and training.

It is aimed for managers of hospitals and other health-care establishments, policy makers, public health professionals and managers involved in waste management.

In order to develop a waste management plan, the waste management team needs to make an assessment of all waste generated in the hospital. The WMO should be responsible for coordinating such a survey and for analyzing the results.

The waste should be categorized according to the classification system specified in the national guidelines. The survey should determine the average daily quantity of waste in each category generated by each hospital department. Special care should be taken to assess the likelihood of peak production -the occasional generation of extraordinary quantities of wastes. Account should also be taken of potential slack periods or other unusual circumstances that may cause significant variations in waste quantities. Survey results should include an assessment of any future changes in hospital designation, departmental growth, or the establishment of new departments. Data from the waste production survey should form the basis on which an appropriate waste management plan can be developed.

During development of the waste management plan, every member of the waste management team should carry out a review of existing waste management arrangements in his or her area of responsibility. Existing practices should be evaluated and on the basis of the national guidelines and the recommendations a discussion document should be prepare for the implemented in each area. This discussion document should include details with the following issues:

- present situation (waste management practices, personnel and equipment involved)
- quantities of waste generated
- possibilities for waste minimization, reuse, and recycling
- waste segregation
- identification and evaluation of waste treatment and disposal options (on- and off-site)
- identification and evaluation of the options, and associated costs
- record-keeping
- training
- estimation of costs relating to waste management (actual situation and proposed options)
- strategy for implementation of the plan.

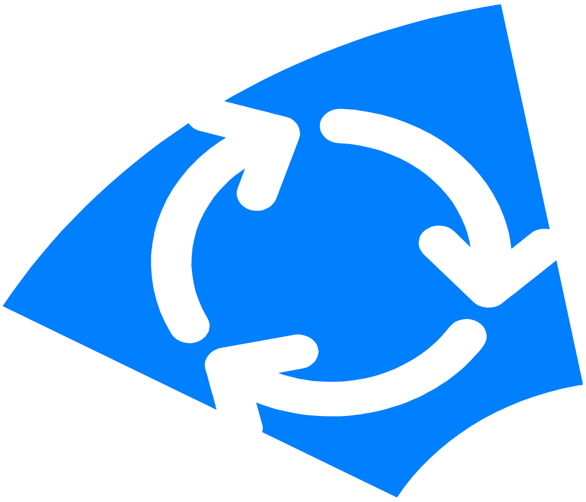
Additionally, WHO guidance documents on health-care waste are now available including:

- a monitoring tool
- a cost assessment tool
- a rapid assessment tool
- a policy paper
- guidance to develop national plans
- management of waste from injection activities
- management of waste at primary health care centres
- management of waste from mass immunization activities
- management of waste in emergencies.

The full text of these publications is available on the WHO water, sanitation and health web site. Finally the goal of a Plan of Action (POA) is to prevent and mitigate the environmental and health impact of Health Care Waste on health care staff and the general public. The objectives are to reduce infections, to improve service and mitigate the impacts on individuals and communities and to establish a well-managed multi-sector institutional framework for co-ordination and implementation of Health Care Waste Management measures. A national program of health-care waste management can be developed through a seven-step plan.

Step 1. Establish policy commitment and responsibility for health-care waste management
Step 2. Conduct a national survey of health-care waste practices
Step 3. Develop national guidelines
Step 4. Develop a policy on regional and cooperative methods of health-care waste treatment

Step 5. Legislation: regulations and standards for health-care waste management
Step 6. Institute a national training program
Step 7. Review the national health-care waste management program after implementation



12.5. Cost estimation

Each healthcare establishment should be financially liable for the safe management of any waste it generates. The costs of separate collection, appropriate packaging, and on-site handling are internal to the establishment and paid as labour and supplies costs; the costs of off-site transport, treatment, and final disposal are external and paid to the contractors who provide the service.
The total costs are generally made up of the elements which have to be considered if the most cost-effective option is to be selected. Certain basic principles should always be respected in order to minimize these costs:

- Waste minimization, segregation, and recycling can greatly reduce disposal costs. The benefits of producing less waste are evident, and segregation prevents the unnecessary treatment of general waste by the costly methods necessary for hazardous waste.
- Designing all elements of the system to be of adequate capacity will obviate the need for subsequent costly modifications.
- Future trends in waste production and the likelihood of legislation becoming more stringent should be foreseen

All hospitals need to establish accounting procedures to document the costs they incur in managing health-care waste. Accurate record-keeping and cost analysis must be undertaken. Health-care waste costs should be the subject of a separate budget line; this allows costs for different periods to be compared and helps to reduce management costs.
Cost reductions can be achieved by taking particular measures at different stages in the management of wastes:
On-site management

(Comprehensive management of chemicals and pharmaceuticals stores, substitution of disposable medical care items, adequate segregation of waste, waste identification to simplify segregation, treatment, and recycling).

Comprehensive planning

(Development and implementation of a comprehensive health-care waste management strategy, planning collection and transport, possible cooperative use of regional incineration facilities, establishment of a wastewater disposal plan).

Documentation

(Waste management and cost documentation: assessment of the true costs).

Choice of adequate treatment or disposal method

(Selection of a treatment and disposal option, appropriate for waste type, use of treatment equipment).

Measures at personnel level

(Establishment of training programs, protection of employees against occupational risks).

12.6. Education and training

A management of healthcare waste cannot be effective unless it is applied carefully, consistently, and universally. So, the aim of training is to develop awareness of the health, safety, and environmental issues relating to health-care waste, and how these can affect employees in their daily work. It should highlight the roles and responsibilities of healthcare personnel. All hospital personnel, including senior medical doctors, should be convinced of the need for a comprehensive healthcare waste management policy and the related training. This should ensure their collaboration in the implementation of such a policy.

Separate training activities should be targeted to four main categories of personnel:

- hospital managers and administrative staff responsible for implementing regulations on health-care waste management;
- medical doctors;
- nurses and assistant nurses;
- cleaners, auxiliary staff, and waste handlers.

Medical doctors may be educated through senior staff workshops and general hospital staff through formal seminars. The training of waste managers and regulators could take place outside the hospitals, at public health schools or in university departments.

The staff education programs should include information on all aspects of the health-care waste policy, information on the role and responsibilities of each hospital staff member and technical instructions, relevant for the target group, on the application of waste management practices. One of the best ways of learning is through practice, and hands-on training of small groups of personnel should be considered where appropriate.

The public education on hazards linked to health-care waste is important for community health, and every member of the community should have the right to be informed about potential health hazards. The objectives of public education on health-care waste are:

- *To prevent exposure* to health-care waste and related health hazards; this exposure may be voluntary or accidental.
- *To create awareness and foster responsibility* among hospital patients and visitors to health-care establishments regarding hygiene and health-care waste management.
- *To inform the public* about the risks, focusing on people living or working near to, or visiting, health-care establishments, families of patients treated at home, and scavengers on waste dumps.

PowerPoint Presentation best practices in healthcare management
http://www.slideserve.com/garvey/regulated-medical-waste

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MORE INFORMATION

Global Alliance for Incinerator Alternatives (GAIA)
Website: http://www.no-burn.org

Health Care Without Harm
http://www. noharm.org

International Solid Waste Association (ISWA)
iswa@iswa.dk

Program for Appropriate Technology in Health (PATH)
info@path.org

The Safe Injection Global Network (SIGN)
www.injectionsafety.org

The Sustainable Hospitals Clearinghouse

http://www.sustainablehospitals.org/

WASTE—Advisors on Urban Environment and Development
www.waste.nl

World Health Organization
Water and Sanitation
www.healthcarewaste.org E-mail: info@wsp.org

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